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CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO THE

ARTS AND MANUFACTURES.

BY

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VOL. II.

— Nitric Acid

FUEL —— ZINC

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Theoretical, Practical & Analytical,

AS APPLIED AND RELATING TO

The Arts and Manufactures.

BY

DR. SHERIDAN MUSPRATT. F.R.S.E. M.R.I.A. F.G.S.

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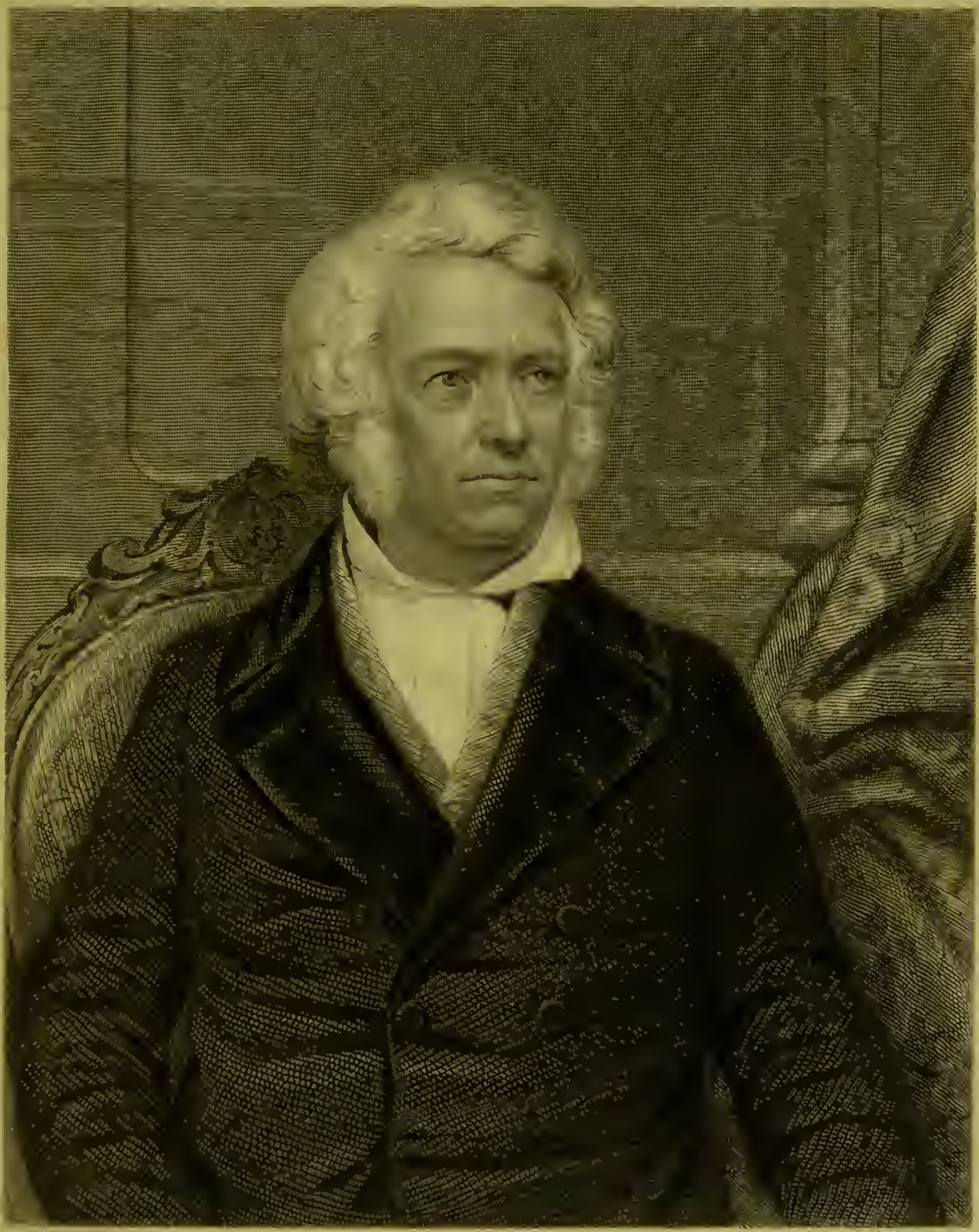

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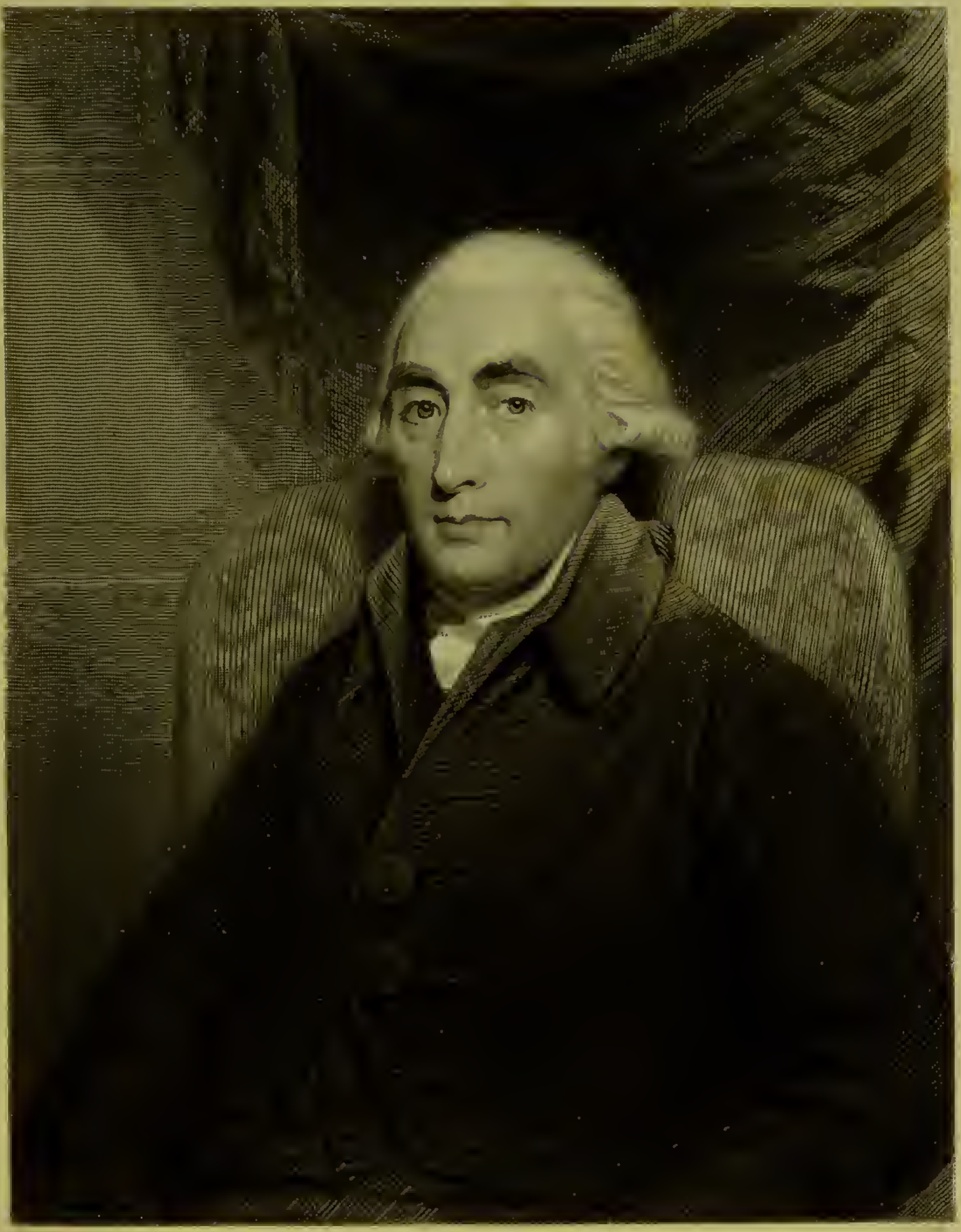

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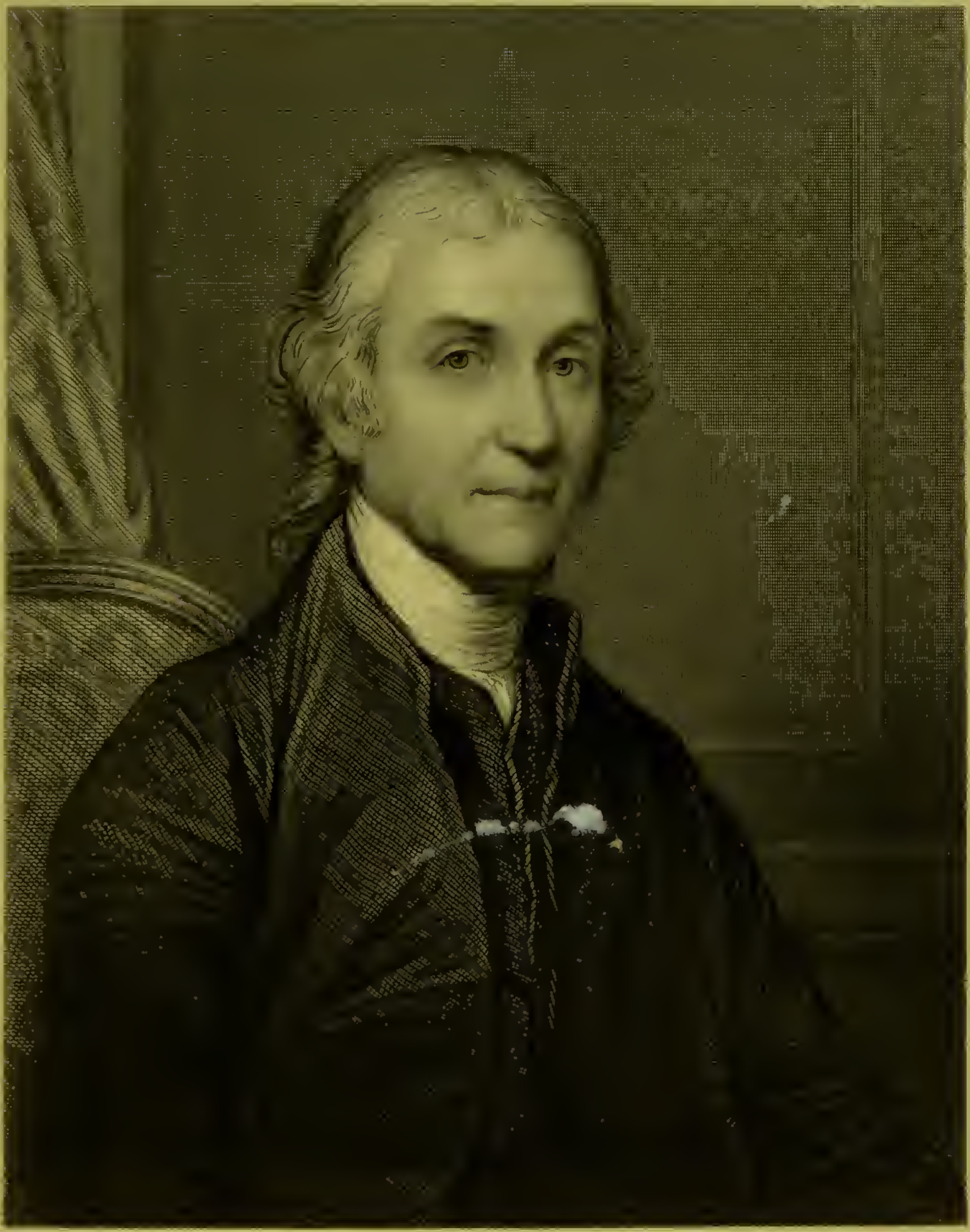

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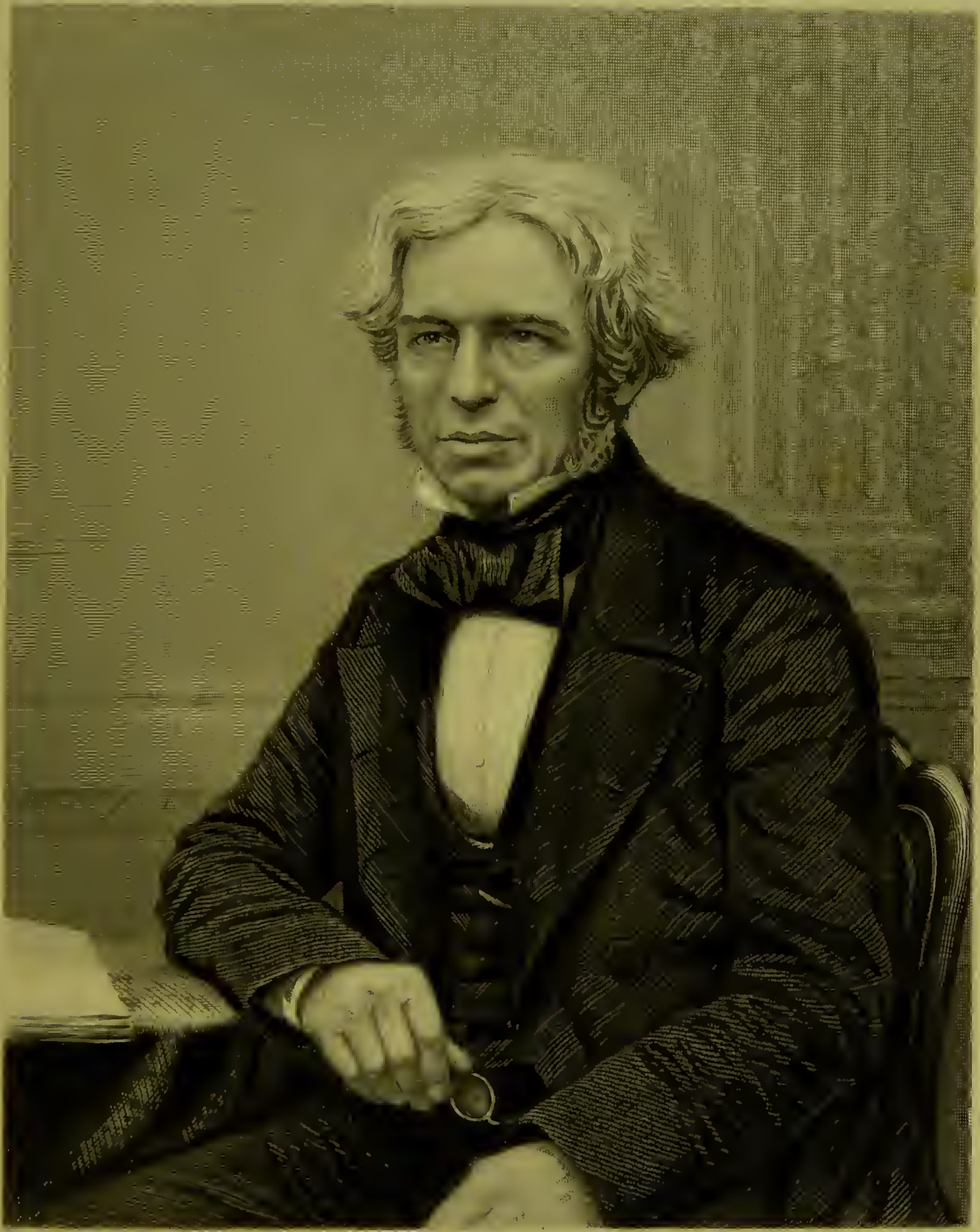

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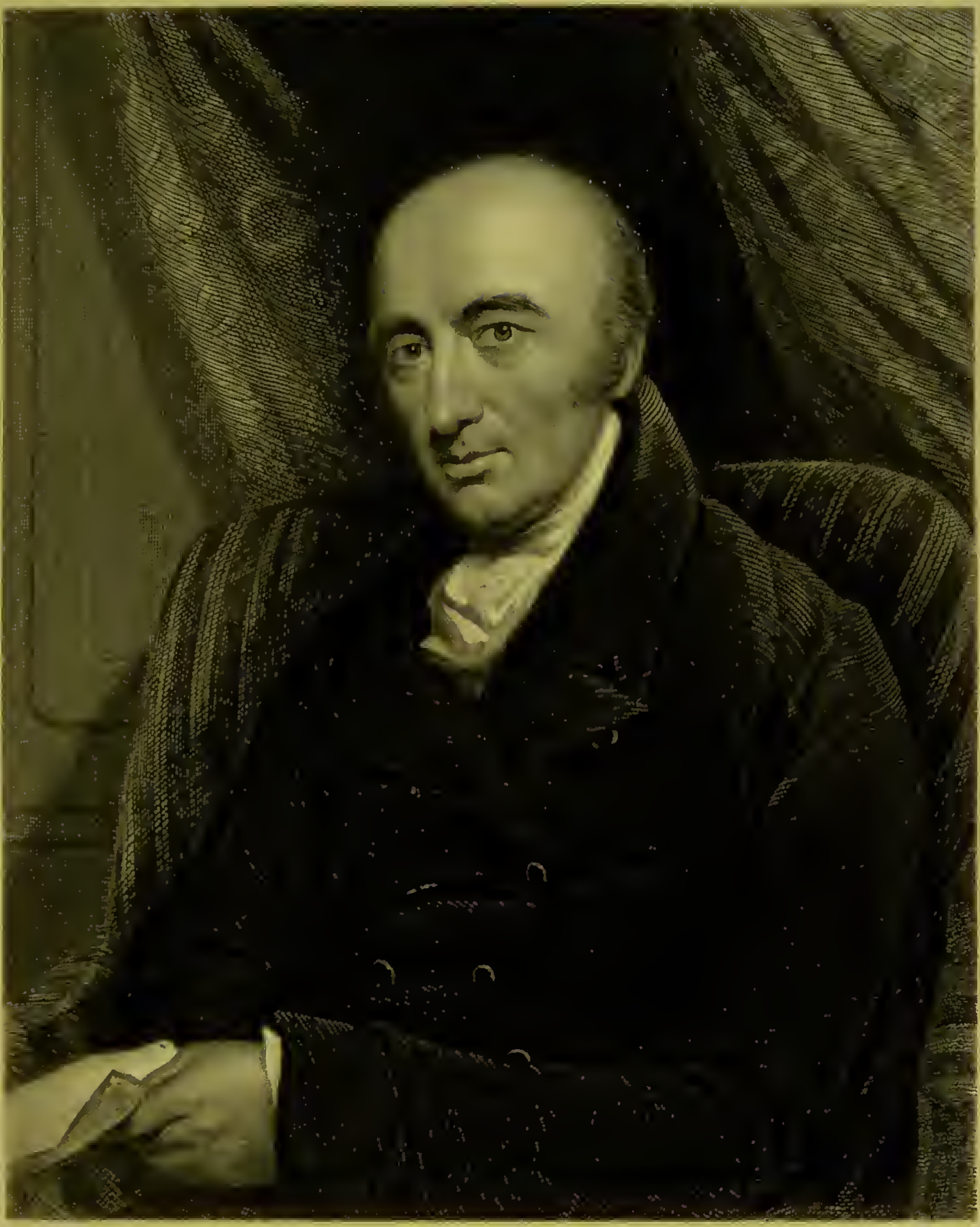

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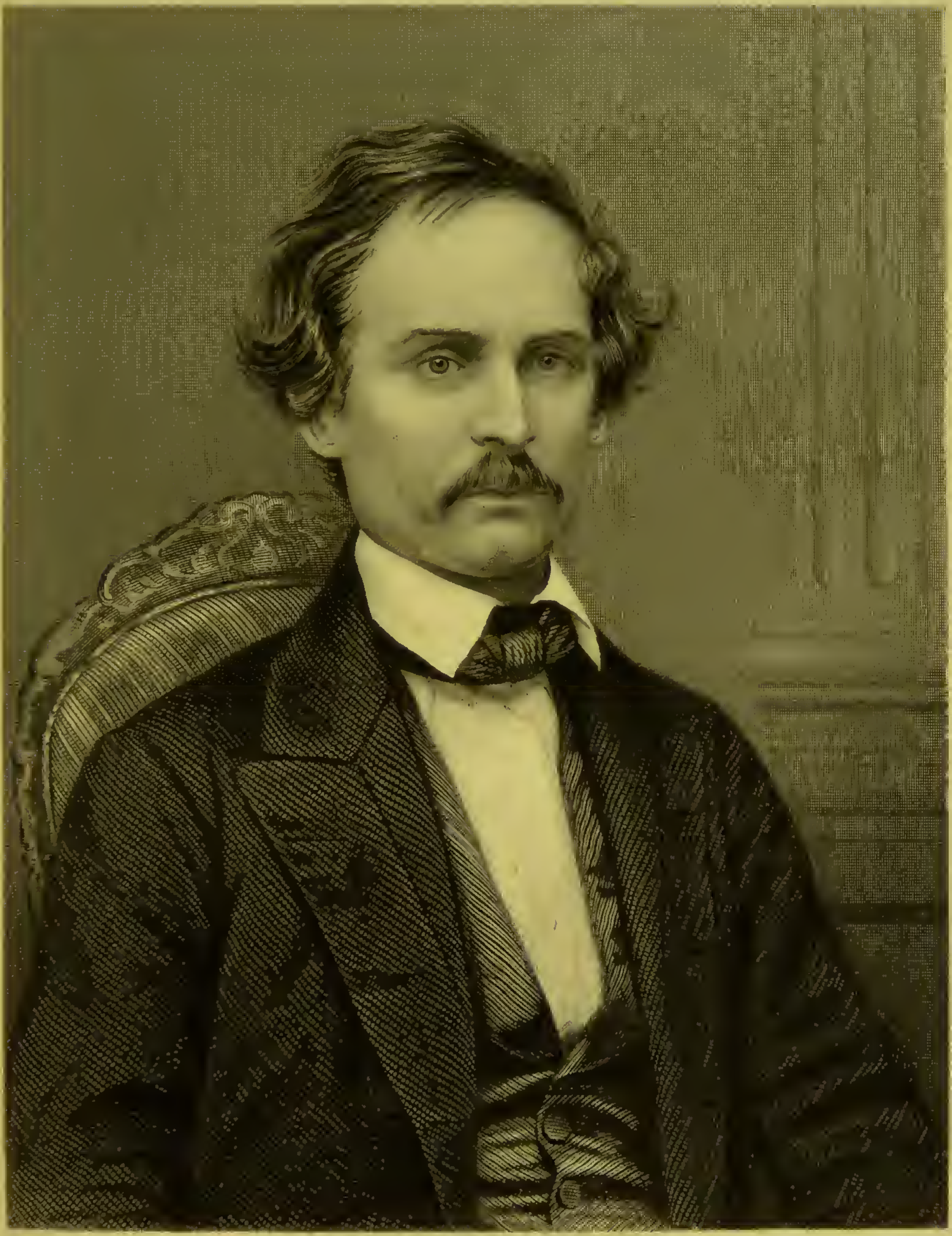

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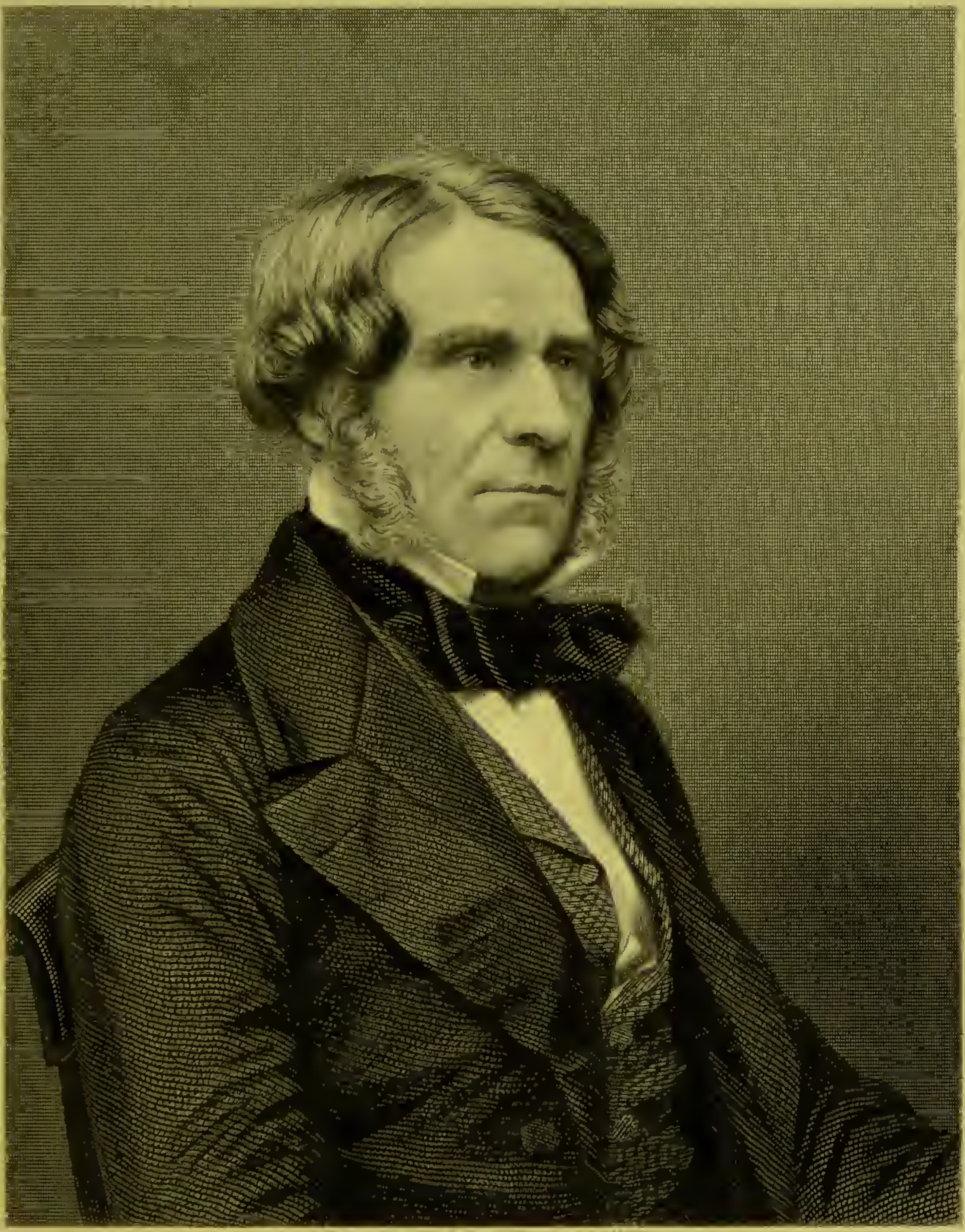

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CHEMISTRY

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO

THE ARTS AND MANUFACTURES.

> There are qualities in the products of Nature yet undiscovered. and combinations in the powers of Art yet untried. It is the duty of every man to endeavor that something may be added, by his industry, to the hereditary aggregate of knowledge and happiness.—Dr Johnson.

FUEL——Nature and Properties of Caloric.

FUEL.—*Combustible*, French; *Brennstoff*, German; *Fomes*, Latin.—The importance which must have been attached in every age, from the earliest period of human existence, to fire, and the necessity which has ever impelled mankind to provide it, not so much for purposes of luxury, as an absolute essential, to enable them to counteract the effects of climate and other external influences which affect the frame, are sufficient, apart from any other consideration, to impress every one with a sense of its usefulness. It is not in reference to these primary applications, however, that the full value of fire, or the extent of its influence, will be understood, but only when it is studied in connection with the various natural and artificial transformations of matter which it produces.

Nations, however rude or barbarous they might have been, always made use of fire: firstly, as a means of preservation; secondly, as a source of comfort or luxury; and lastly, as a destructive agent. The history of its application in relation to these three objects would offer a comprehensive view of the advance of civilization. Not only do the attributes of fire exert a gigantic influence in the various social requirements, but in the most minute as well as the most elaborate changes which take place in nature. Heat and light, indeed, seem to be the life-giving principles of the material world, and are not less essential to man in subduing matter to his service.

Among the material sources of heat, all the substances chemically termed *combustible*, such as carbon, sulphur, phosphorus, potassium, iron, *et cetera*, may be regarded as particular kinds of fuel, although the name is usually restricted to organic products of ligneous origin, such as woody matters, coal, peat, and the like.

As the consideration of fuel is intimately associated with heat, and as this is a subject of great practical importance, it will be necessary to enter into somewhat lengthened details in regard to the nature of caloric—the term applied to the substance or cause of heat, in contradistinction to the sensation which it produces. This theoretical inquiry is essential to a full understanding of various processes and instruments mentioned in the present work, and more especially is it indispensable to a complete elucidation of the nature and action of fuel; or, in other words, of those substances employed to generate that principle which constitutes the great agent, not only in impelling machinery, but in most manufacturing operations. The Editor will, therefore, make no apology for entering here at considerable length into a preliminary exposition of the nature of heat or caloric.

Nature and Properties of Caloric.—Of the three imponderables—caloric, light, and electricity—caloric is that which produces the sensation of heat or warmth in animal bodies. It exists, however, in considerable quantities, even when it cannot be distinguished by this test.

Substances communicate a warm sensation when their contained heat exceeds that of the part of the body which touches them; and they are said to be cold when the heat of the latter is greater. Hence it is evident that heat and cold are merely relative terms, and do not indicate the actual amount of caloric which is contained in any body. This can be readily proved by exposing the two hands to unequal degrees of temperature, and then bringing them in contact with a body containing an intermediate quantity; the heated hand will experience the sensation of cold, and the other of heat; that is to say, the same substance will communicate the sensation of heat or cold, according to the temperature of the part of the body touching it.

Caloric is self-repulsive, and eminently destroys cohesion, because it induces the particles of matter to separate to a greater or less distance, according to the amount of it which combines with them—thus producing what is termed *expansion* or *dilatation*. It pervades and penetrates all bodies, however compact they may be, and seems to be in constant intercommunication between them, more especially if they are possessed of it in unequal quantities. In its passage from any one body to surrounding objects, it emanates in direct lines with a velocity hitherto undetermined, but supposed to be equal to that of light. Its intensity, also, diminishes in the ratio of the square of the distance from the heated body. Thus, if at the distance of one foot from the source of heat the effect be accounted unity, at two feet it will be only one-fourth as much, at three only one-ninth, and so on. Heat may be conveyed from one body to another in three ways: firstly, it may pass from one particle to another when the substances are in contact; secondly, it may be emitted in direct lines to a distance; and, thirdly, it may be received after passing through another body which offers little resistance to it. In the first of these cases, it is said to be *conducted*; in the second, *radiated*; and in the third, *transmitted*. In many of its properties it resembles light—more especially in the facility with which it is reflected and refracted. The phenomena of dew, wind, frost, snow, and other atmospheric changes, are consequences of the unequal amount of caloric combined with water.

Sources of Caloric.—Among the acknowledged sources of heat—namely, the sun, electricity, chemical and mechanical action—some enumerate vital action; but this may be regarded as included in the preceding list, for its operations may be referred to the united effects of chemical and mechanical action.

The heat of the sun has been approximately estimated by Pouillet, as between 2662° and 3202° Fahr. When the rays of this luminary are concentrated either by lenses or reflectors, a great amount of caloric may be brought to operate on bodies at a considerable distance. Buffon ignited a board of tarred beech with forty reflectors, at a distance of sixty-six feet; with the power of one hundred and twenty-eight mirrors he set on fire a tarred pine plank, which was one hundred and fifty feet distant. Pieces of coin and other metallic matters were readily melted by this means.

Electricity supplies a heat so intense as to be capable of fusing and even volatilizing matters which, under ordinary circumstances, resist the action of the hottest furnace. Indeed, by galvanism, the highest temperature hitherto obtained has been produced.

Chemical action is, next to the sun's rays, the commonest and most useful source of heat, and the methods of generating it in this manner are various; but that which is best known and most frequently resorted to is combustion. By *combustion* is usually understood that change which a body undergoes on being ignited in the air, and by which light and heat are evolved, whilst the substance itself disappears. Chemically considered, however, combustion is the effect of the union of two or more elements, whereby heat is always disengaged, though light is not a necessary consequent in every instance. Thus, in numerous chemical combinations, considerable quantities of caloric are set free, unattended with luminousness. Animal or vital heat is generated principally by the chemical changes which the food as well as the components of the body are constantly undergoing; and the movements of the members contribute to its more rapid production.

Finally, mechanical action, either by percussion or friction, is capable of disengaging heat from bodies in large quantities. For instance, if a bar of iron be struck with a hammer, a certain amount of caloric will be evolved at every stroke; and by vigorously continuing the action the bar may be made red-hot. But after a rod of metal which has been rendered incandescent by this means has once cooled, no amount of mechanical force is afterwards sufficient to bring it again to a glow, unless it be heated in the fire and allowed to cool. This is owing to the circumstance, that the metal cannot secrete in its condensed state as much latent heat as would be necessary to raise its temperature when further compressed; for the evolution of heat by percussion appears to depend upon the compression of the particles of the body struck. Berthollet measured the amount of caloric emitted from the strokes of a coining-press; he found that, at the first stroke, it gave off 17·3°, at the second 7·5°, and at the third only 1·9°.

Friction is another mechanical means of producing or developing caloric. Instances of this are familiar to engineers, and workers in metal who are engaged in boring, filing, *et cetera*. Even the rubbing of one piece of ice against another may be made to produce an evolution of heat sufficient to melt both, and this will take place more or less quickly according to the amount of force applied in the friction. Count Rumford ascertained that the heat liberated in boring a piece of cannon seven and a half inches in diameter, the instrument making thirty revolutions per minute under a pressure of ten thousand pounds, was sufficient to boil eighteen pounds of water in two hours and a half. If a bar of steel be forcibly struck against a piece of flint or other hard body, the caloric which is set free will be sufficient to cause the combustion of the particles of the metal which are disengaged, and which are seen to fly off in sparks.

Expansive Action of Caloric.—The effects of caloric upon matter are various; but that which is most important, and which will require to be considered first, as affording a convenient measure of its intensity, is its *expansive action*. The distribution of matter into aeriform, liquid, and solid bodies depends on this principle. Many bodies possess the quality of uniting with heat and retaining it to such an extent, that they remain permanently liquid or gaseous, whilst other compounds, having less of the same principle, are solid at ordinary temperatures. In rendering solid bodies aeriform and liquid, the self-repulsive action of the heat overcomes the cohesive force with which the particles were held together, and separates them to a certain distance, dependent upon the amount of caloric absorbed. When a bar of brass strongly heated is placed upon another one of a different kind, but which is an imperfect conductor, for instance lead, the repulsive action of heat will be shown by the evolution of sound. This happens in consequence of caloric being communicated by the heated metal to the lead in contact with it, but not being immediately conducted to other particles of the latter metal, repulsion follows, and the hot body is thrown out of close union; descending, however, by the force of gravity, it again comes in contact with the lead, or nearly so. This contact is immediately broken off, and again renewed, the movement thus continuing in rapid succession till the brass cools. The vibration gives rise to musical sounds. BADEN POWELL ingeniously measured the force of the self-repulsion of heat by means of colored rings. A flat and convex glass plate were strongly pressed together, and the colored rings formed by the refraction of light from the thin stratum of air between, afforded him the means of estimating the repulsive force; for when heat was applied to the lower plate, the rings altered and closed in towards the centre, showing that the glass plates receded from one another. Now, as each of the annular colors has a certain determinate thickness, it is evident that the degree of repulsion may be ascertained from the narrowing which occurs in the breadth of the rings as the temperature rises.

The expansion or dilatation produced in bodies by heat is a familiar phenomenon. Very great difference exists, however, as to the extent to which different substances are affected by the same amount of heat. In such compounds as are permanently gaseous, no opposition is offered to the distending power of the combined caloric, and the result is, that these dilate in a regular and uniform ratio, no matter how hot or cold they may be when the caloric is communicated. It is different with solids and liquids, in which the resistance offered by the varying force of cohesion must first be overcome before any discernible repulsion of the particles succeeds. Where this opposing force is great, it is evident that a much larger amount of heat will be required to distend them. Hence the difference in the rate of expansion of bodies produced by this agency.

The Thermometer.—The thermometer, or heat-measurer, is constructed upon the principle of the expansion of bodies by caloric. It consists, in its common form, of a glass tube terminating in a bulb containing mercury or some other fluid, which fills the bulb and part of the tube; and the rise or fall of the fluid in the tube, according as the mass of it in the bulb expands or contracts, indicates the changes of temperature in the surrounding medium. This most indispensable instrument was not known previous to the sixteenth century, and, at its first introduction by the Florentine academicians, its indications were not very trustworthy. At first, the change of the amount of caloric was estimated by the expansion of air; but this, although in common with other aeriform fluids more regular than liquids or solids in its alteration of volume by increased or diminished temperatures, offered so much inconvenience in the wide extent of its range, besides being largely affected by the varying pressure of the atmosphere, that it was found necessary to substitute another fluid. Various liquids, such as linseed oil and spirit of wine, were tried with good effect; but, for general purposes, mercury was found to be the most suitable. The range between its points of solidification and ebullition is greater than that of any other known fluid; it is also a good conductor of heat, and is, consequently, rapid in its indications, and sensitive to sudden changes of temperature. It is true that it experiences, like other fluids, as will be explained afterwards, a constantly increasing rate of expansion as the temperature rises, but between the freezing and boiling points of water this irregularity is so minute, as to be really of little or no moment even in very accurate investigations; indeed, the slight deviation which takes place is nearly compensated by the glass, which expands in much the same proportion as mercury.

There are three varieties of this instrument, differing merely in the notation. FAHRENHEIT, whose thermometer is generally used in this country, fixed the zero of his scale at the temperature of a mixture of snow and salt, and divided the interval between this and the boiling point of water into two hundred and twelve equal parts or degrees, so that on this scale water freezes at 32°, and there are 180° between its freezing and boiling points. CELSIUS, in constructing his modification of the thermometer, assumed as the zero of his scale the freezing point of water, and, proceeding on the decimal principle, divided the interval between this and the boiling point into one hundred equal parts, so that on this scale the point of ebullition is indicated by 100°. Hence, his instrument, which is used extensively on the Continent, has been called the Centigrade. In REAUMUR'S scale, as in the Centigrade, the freezing point is the zero; but the distance between the freezing and boiling points is in REAUMUR'S divided into 80 equal parts, instead of 100, so that on this scale the boiling point of water is at 80°. In each of these thermometers the degrees of temperature under the zero are indicated by the sign *minus*. Thus, —15° Fahr. indicates fifteen degrees of that scale below the temperature of a mixture of snow and salt; while the same notation on the Centigrade or Reaumur scale signifies a temperature fifteen degrees of the one or the other of these scales below the freezing point of water.

By very simple formulæ, the degrees of any of these thermometers may be converted into the equivalent of the others. The same distance is divided in the three thermometers into 180° in Fahrenheit's, 80° in Reaumur's, and 100° in the Centigrade. Now, dividing by twenty, it will be seen that these numbers are in the ratio of 9 : 4 : 5; or, in other words, nine degrees of Fahrenheit's scale are equivalent to four degrees of Reaumur's, and five of the Centigrade. Hence, indicating the respective thermometers by the initials F., R., C., the length of a degree in each will be as follows:—

$$1^\circ\ \text{F.} : 1^\circ\ \text{R.} : 1^\circ\ \text{C.} :: \tfrac{1}{9} : \tfrac{1}{4} : \tfrac{1}{5}$$

But the temperature is measured by the number of divisions contained in equal portions of the stem of the respective thermometers. Now, the zero point of Fahrenheit's is 32° below freezing point. If, therefore, F.° — 32, R.°, C.°, indicate the same temperature on each of the three thermometers, one has the proportion:—

$$\text{F.}^\circ - 32 : \text{C}^\circ : \text{R.}^\circ :: 9 : 5 : 4$$

whence result the following equations for converting one scale into another:—

$$4\ (F.^\circ - 32) = 9\ R.^\circ$$
$$5\ (F.^\circ - 32) = 9\ C.^\circ$$
$$5\ R.^\circ = 4\ C.^\circ$$
or,
$$\tfrac{1}{9}\ (F.^\circ - 32) = \tfrac{1}{4}\ R.^\circ = \tfrac{1}{5}\ C.^\circ$$

The divisions principally used are those of Fahrenheit and the Centigrade, and the equations for passing from the indications of the Centigrade to those of Fahrenheit, and *vice versâ*, are—

$$F.^\circ = 32 + \tfrac{9}{5}\ C.^\circ$$
$$C.^\circ = \tfrac{5}{9}\ (F.^\circ - 32)$$

that is, add thirty-two to nine-fifths of the number indicated on the Centigrade, and the result is the number which would be indicated by Fahrenheit; subtract thirty-two from the number indicated by Fahrenheit, and five-ninths of the remainder is the number which would be indicated by the Centigrade.

When very low temperatures, under —40° Fahr., have to be estimated, a mercurial thermometer cannot be employed, since this metal solidifies at that point; in such cases, alcohol colored by some matter is used in the bulb of the instrument. On the other hand, mercury boils at about 600° Fahr., and, therefore, when very high temperatures are to be estimated, a different instrument, termed the pyrometer, is employed, which will be described in the sequel.

Whatever be the form of thermometer, it is evident that the indications are merely relative, and do not express the actual amount of caloric which a substance contains. The use of the thermometer, therefore, is merely to indicate the sensible heat, or that which is capable of being radiated or communicated from one material to another; and for this purpose it is of most important application in various branches of the arts and manufactures, serving for the guidance of the operatives in numerous processes, to the success of which it is absolutely indispensable.

Expansion of Solids.—The rate of expansion in solid bodies is greatly dependent on their state of aggregation; hence it will be evident that the same amount of caloric will operate differently on different solids, but the effect is more visible in the metals than upon other solid non-metallic substances.

The following table exhibits the rate of expansion of a few solids when heated from 32° to 212°:—

TABLE OF EXPANSION FROM 32° TO 212° FAHR.

Name.	Expansion in length.	Do. in bulk.	Authorities
Zinc, cast, ...	1 in 323		
„ sheet, ...	1 „ 340	.. 1 in 113	Smeaton.
Lead, ...	1 „ 351	.. 1 „ 117	Lavoisier and Laplace.
Tin, ...	1 „ 516	.. 1 „ 172	
Silver, ...	1 „ 524	.. 1 „ 175	
Brass, ...	1 „ 536	.. 1 „ 179	
Copper, ...	1 „ 582	.. 1 „ 194	
Gold, ...	1 „ 682	.. 1 „ 227	
Bismuth, ...	1 „ 712	.. 1 „ 239	Smeaton.
Iron, ...	1 „ 846	.. 1 „ 282	Dulong and Petit.
Antimony, ...	1 „ 923	.. 1 „ 307	Smeaton.
Tempered steel,..	1 „ 926	.. 1 „ 309	Lav. and Lap.
Palladium, ...	1 „ 1000	.. 1 „ 333	Wollaston.
Platinum, ...	1 „ 1131	.. 1 „ 377	Dulong and Petit.
Glass without lead,	1 „ 1148	.. 1 „ 382	
Flint glass, ...	1 „ 1248	.. 1 „ 416	Lav. and Lap.

From the foregoing results it is evident that the expansion in bulk is about three times as great as the linear expansion; or, in other words, by multiplying the latter by three, the product will approach closely to the increase in bulk. It must be observed, however, that the expansion is not uniform for equal increments of temperature, for all bodies tend to expand more as the heat reaches a high degree. This is especially the case with metals; hence it is that mercurial thermometers are not well adapted for measuring degrees of temperature much higher than that of boiling water, owing to the increase of the metal at high heats being greater than at low. The rates of expansion in mercury from 32° to 572° are—one in 55·08 between the freezing and boiling points of water; one in 54·61 between the latter and 392°; and one in 54·01 between this and 572°.

The extent to which glass expands when heated within the same range is given in the table annexed:—

Temperature by air thermometer.	Mean absolute dilatation of glass for each degree.	Temperature by [illegible]
From 32° to 212	$\frac{1}{69660}$	212°
„ 32° to 392	$\frac{1}{65340}$	415·8
„ 32° to 572	$\frac{1}{59220}$	667·2°

Most solids return to their original volume when they have parted with the caloric which caused the distention of their particles; some, however, are incapable of doing so, and are permanently elongated or enlarged every time they are subjected to the influence of a high temperature. Such is the case, more especially, with zinc and lead—the particles of which, in sliding over each other, are supposed to possess an amount of adhesive friction which prevents their retraction to the full extent they had expanded.

The expansion or contraction of bodies, occasioned by an increase or diminution of temperature, takes place with enormous force. The amount of this has been estimated by **Barlow**, who found that a bar of metal, of one square inch section, is elongated one ten-thousandth of its length by receiving an addition to its temperature of 16°; to produce the same effect mechanically would require a ton weight to be suspended from it, or the application of an equivalent force. A careful attention to this subject is indispensable in the sciences of engineering, horology, *et cetera.* It has been found that within the usual range of the variation of the temperature of England throughout the year, a bar of wrought-iron, ten inches long, will expand about two hundredths of an inch. Were both its extremities secured firmly to other objects, this change would exert a force, tending towards their removal, of fifty tons to the square inch: hence it is to be observed that where beams of wood are to be replaced by iron ones, care should be taken that room for occasional expansion should be allowed them, otherwise very ruinous consequences might result. From the numerous and varied uses to which iron is now applied, this is a subject of very great importance. An accurate calculation must be made, and the structure so formed, as that the expansion or contraction of the metal shall not endanger its stability.

A very ingenious application of the power obtained by the enormous force of the contraction of metals was made by **Molard**, to secure the Museum of Arts and

Manufactures in Paris, by restoring the walls, which were giving way outward owing to the weight of the roof. His method was to insert bars of iron horizontally through the building, so as to protrude a little from the walls at each side. Heat was then applied by lamps suspended over the whole length of the bars, and the metal expanded to some extent, after which iron nuts were firmly screwed on the bars at both ends, and tightened to the wall as much as possible; the heat being now removed, the metal began to contract, and in doing so, it drew the nuts closer together, which had the effect of bringing the walls nearer to the perpendicular. By a repetition of the heating of the bars, and again tightening the nuts or plates, the bulges were entirely removed, and the walls were restored to their vertical position. In many of the ordinary arts of life a similar advantage has been taken of the effect of heat upon bodies to render peculiar service; the wheel-wright, by heating the tire and fitting it on in an expanded state, and then allowing it to contract, insures the firmness and durability of the wheel; the cooper, in like manner, heats the hoops of his casks, *et cetera*, when fitting them in their proper place, so that when they cool they may bind the staves more firmly; and the boiler-maker uses red-hot rivets as well for facilitating their plating, as for binding the sheets of metal more tightly by their subsequent contraction on cooling.

The sudden application of heat to many bodies is productive of fracture, owing to a partial expansion of the part heated, while the part not so affected refuses to yield. This is frequently seen in glass and cast-iron plates. Indeed the most delicate part of the glass-maker's business, as will be seen in a future article, is the annealing; or, in other words, the exposure of the goods to a gradual cooling, which renders them less liable to crack when exposed to sudden changes of temperature.

A tabular statement of the rate of expansion of a few of the metals is subjoined, with a comparative view of the results when the temperature is measured with the air thermometer, and with one constructed of the metals under experiment:—

Temperature by air thermometer.	Mean dilatation of iron for each degree.	Temperature by iron rod thermometer	Mean dilatation of copper for each degree.	Temperature by copper thermometer.	Mean dilatation of platinum for each degree.	Temperature by platinum thermometer.
212°	$\frac{1}{50760}$	212°	$\frac{1}{34120}$	212°	$\frac{1}{67800}$	212°
572°	$\frac{1}{40678}$	702°5	$\frac{1}{31800}$	623°8	$\frac{1}{63310}$	592°9

In estimating the temperature at high degrees by a mercurial thermometer, the observations made as to the rise of the metal indicate only the difference between the expansion of the glass and that of the metal, which, in ordinary cases, is supposed to be uniform; but owing to the increased expansion which the mercury experiences at a high temperature, 572° on the air thermometer corresponds with 586° on the mercurial one. The same temperature estimated by glass alone would be indicated by 667°, thus showing that the dilatation of the glass counteracts the expansion of the fluid metal. Considerable difference will be observed in the table between the indication of the air thermometer and that which is found by measuring the expansion of bars of metal; so that at high temperatures, which liquids and gaseous bodies cannot be employed to measure, the true indication of heat, as compared with the air thermometer, is somewhat difficult to ascertain. A further obstacle stands in the way, inasmuch as the rate of expansion in metals and most solid bodies is unequal. M. Breguet contrived to overcome this by constructing a solid thermometer, composed of a compound ribbon of three metals —gold, platinum, and silver—rolled out very thin and coiled spirally. The upper end of these was fixed, and the lower one attached to an index which described an arc, as the helix twisted or untwisted, by the greater expansion or contraction of the silver band over the platinum one. By graduating the range of the index, and finding the value of the indications by comparing them with those of a standard thermometer, the instrument was completed.

The Pyrometer.—When the temperature is very high, such as that at which the more infusible metals melt, or of a reverberatory or wind furnace, the common thermometer is unavailable, and other instruments for estimating the heat have been invented, which are called *pyrometers*. Of these, Daniell's register pyrometer, represented in Fig. 1, is the most accurate. It consists of two parts, namely, the register and the scale. The register is a solid bar of black-lead, highly baked, in the axis of which is drilled a hole reaching to within half an inch of the end; into this hole a bar of iron, or of platinum, *a a*, is introduced. A cylindrical piece of porcelain, *c*, sufficiently long to project a short distance from the extremity, is placed endwise upon the iron, and the former is bound to the bar by a band of platinum, *d*, passing round both, and tightened, if necessary, by a wedge of porcelain, *e*. When this instrument is exposed to a very high heat, the whole increases in bulk, in proportion to its intensity; but the rate of expansion of the metal and of its casing being unequal, the porcelain cylinder, *c c*, will be protruded to the extent of the difference.

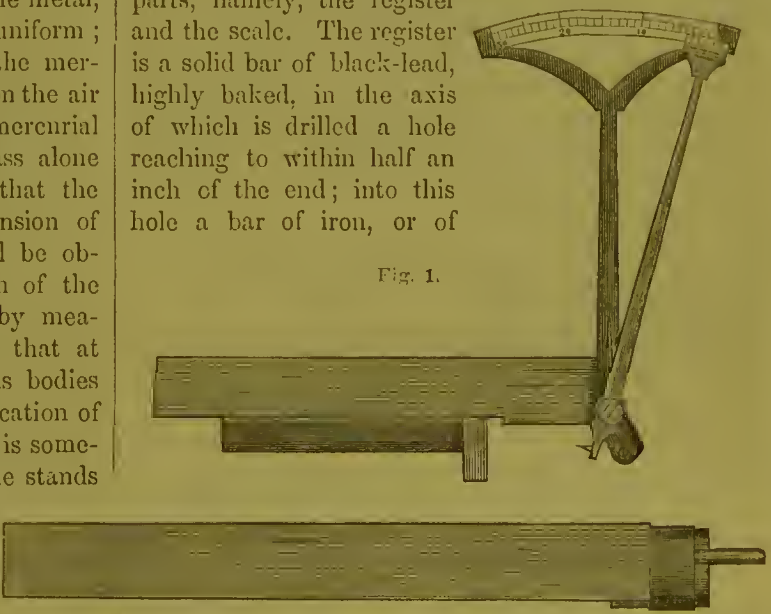


Fig. 1.

To measure the length of the protruded portion, the scale is applied. This consists of two brass rules, *f, g*, joined together by screws, to form a right angle, and fitting exactly upon the sides of the register. The plate, *h*, rests on the shoulder of the bar, A, formed for the platinum band. At the extremity of the rule nearest this, an arm, D, movable upon its centre, *i*, is fixed; and at the other an arc of a circle, E, graduated into degrees and thirds of degrees. Upon the latter, at *h*, is another lighter arm, C, carrying upon the end of its longer limb a nonius, H, which moves upon the face of the arc, E, and subdivides the graduations into minutes. The other end of this arm protrudes beyond the centre of motion, and carries a steel knife-edged bar, which fits into the notch cut for it in the termination of the index.

The index bar is pressed firmly down upon the metal encased in the black-lead, and securely fixed there by the wedge and band of platinum; the bar is then nicely adjusted in the angle formed by the two rules of the scale; the plate, *h*, firmly held against the shoulder, and the knife edge, *m*, resting in the notch in the index bar; the position of the latter is now noted on the scale, and after the register has been heated and allowed to cool, the scale is again applied and the result observed—the difference is the value of the expansion of the metal bar. By comparing this with the indications given by a mercurial thermometer between any two points, say that of the freezing and boiling of water, an expression in degrees of Fahrenheit's scale may be given to any degree of artificial heat measurable by the instrument.

DANIELL, with this apparatus, obtained the following results, in which the expansion is shown at three stages:—

1,000,000 parts at 62°.	At 212°.	At 662°.	At fusing point.	
Black lead ware,	1,000,244	1,000,703		
Wedgwood ware,	1,000,735	1,002,995		
Platinum,	1,000,735	1,002,995	1,009,926	maximum, but not fused.
Iron—wrought,	1,000,984	1,004,483	1,018,378	to the fusing point of cast-iron.
Iron—cast,	1,000,893	1,003,943	1,016,389	
Gold,	1,001,025	1,004,238	——	
Copper,	1,001,430	1,006,347	1,024,376	
Silver,	1,001,626	1,006,886	1,020,640	
Zinc,	1,002,480	1,008,527	1,012,621	
Lead,	1,002,323	——	1,000,972	
Tin,	1,001,472	——	1,003,798	

Expansion of Liquids.—In liquids, the expansion produced by heat is much more marked than in solids; they also differ among themselves in the amount of expansion produced by equal increments of heat. The most volatile liquids, or those of which the boiling point is low, are found to be the most expansible under the influence of an increase of caloric, as may be observed from the appended table, showing the comparative increase in volume of several liquids when heated from 32° to 212°:—

Water,	0·0466	Dalton.
Saturated solution of chloride of sodium,	0·0500	"
Concentrated sulphuric acid,	0·0600	"
Hydrochloric acid, specific gravity 1·137	0·0600	"
Nitric acid, specific gravity 140	0·1100	"
Alcohol, specific gravity 0·817	0·1100	"
Ether,	0·0700	"
Oil of turpentine,	0·0700	"
Fat oil,	0·0800	"
Mercury,	0·02000	"
"	0·01887	Cavendish.
Mercury,	0·01848	Lavoisier and Laplace.
"	0·01818	Hallstrom.
"	0·01801	Shuckburgh.
"	0·01800	Petit and Dulong.
"	0·01786	Deluc.
"	0·01665	Roy.

A difference in the boiling point of liquids, however, does not always show a corresponding variation in their expansion, as was long ago proved by LAVOISIER with regard to alcohol and bisulphide of carbon, two liquids differing in their boiling points by 57°, yet the rate of expansion is the same in both for each increase of an equal number of degrees of heat, reckoned from their respective boiling points. PIERRE found similar results in his researches upon liquids of analogous composition, such as the bromides and iodides of ethyl and methyl. This relation, however, does not appear between some of the isomeric bodies examined, as may be seen from the annexed table, showing the

CONTRACTION FROM THE BOILING POINTS:—

Name of Liquid.	Boiling point. Fahr.	Temperature equidistant from the boiling point of each group.	Interval between the preceding temperatures.	Volume at boiling point.	Volume at equidistant temperatures.
FIRST GROUP.					
Sulphide of carbon,	118·22°	22·72°	140·94°	1	0·913039
Alcohol,	172·94	32	140·94	1	0·914452
Wood spirit,	151·34	10·4	140·94	1	0·905819
SECOND GROUP.					
Bromide of ethyl,	105·26	32	73·26	1	0·944375
Bromide of methyl,	55·4	17·86	73·26	1	0·944575
THIRD GROUP.					
Iodide of ethyl,	158	32	126	1	0·918704
Iodide of methyl,	110·84	15·16	126	1	0·916643
FOURTH GROUP.					
Formiate of oxide of ethyl,	127·22	20·12	107·1	1	0·910223
Formiate of oxide of methyl,	139·10	32	107·1	1	0·918750

With reference to the second law which governs the expansion of liquids—namely, that they are progressively more expansible at higher than at lower temperatures—it is to be remarked, that in this respect considerable difference exists between different liquids; and in mercury the higher expansion at higher temperatures is less than in any other fluid body. Hence, it is better adapted than any of them for the construction of thermometers. The expansion which takes place in each of the substances enumerated in the following table, between the freezing and boiling points of water at the ordinary pressure, is represented by one hundred parts, and the increase which equal increments of heat produce above 212° is proportionally estimated:—

		Dulong and Petit.			
Air.	Mercury.	Platinum.	Copper.	Iron.	Glass
0	0	0	0	0	0
100	100	100	100	100	100
150	151·3				
200	204·6				
250	255·1				
300	314·15	311·6	328·8	372·6	352·9
350	360				

Water, within the range of its solidifying point and that at which it becomes an elastic vapor, is subject to very great irregularities. The general law, as before expressed, is, that heat exerts an expansive force upon all bodies; but, within a certain range, water becomes an exception. If this liquid be taken in the solid state, or at the temperature of 32°, before it has solidified, and caloric be communicated to it, instead of expanding, it actually contracts till it marks about 39·4°, at which it has attained its greatest density. Above this, it expands in the same ratio that the contraction took place for an equal number of degrees, but beyond that point it obeys the general law.

Count Rumford found the contraction of water for every 22·5° from the boiling to the freezing temperatures to be as follows, namely:—

In cooling, 22·5°	from	219° to 189·5°,	2000 measures of water	contracted	18	measures.
"	"	189·5° to 167°,	"	"	16·2	"
"	"	167° to 144·5°,	"	"	13·8	"
"	"	144·5° to 122°,	"	"	11·5	"
"	"	122° to 99·5°,	"	"	9·3	"
"	"	99·5° to 77°,	"	"	7·7	"
"	"	77° to 54·5°,	"	"	3·9	"
"	"	54·5° to 32°,	"	"	0·2	"

The dilatation of water, when reduced in temperature below 39·4°, serves a purpose of the greatest consequence in the economy of nature—namely, in preventing the transmission of cold beyond the surface of the water in very rigorous seasons, and preserving the chief bulk of the fluid at such a temperature as is congenial to the life of the animals that inhabit it. The fusible alloy of Rose possesses properties in some respects analogous to water. This substance increases in bulk till it reaches about 111°, after which it contracts when its temperature is being raised from this to 156°, the point of its greatest density, and at which its bulk is less than when at the freezing point of water; after this, however, it continues to expand till it reaches its fusing point at 201°.

Expansion of Gases.—The third class of bodies to be considered in relation to the expansive force of heat, are gases. All these being at ordinary temperatures in a state in which the atomical aggregation manifests a highly repulsive tendency, it is evident that they will be influenced to a greater extent by caloric than either of the foregoing classes. A remarkable coincidence or uniformity, however, is found to exist among the different members of this class; and, knowing the rate of expansion of one when combined with a certain amount of caloric, the same may be taken as the expansive power of the other permanent gases and elastic vapors when subjected to an equal increase of temperature. By former investigations, this was found to amount to about three hundred and seventy-five parts in a thousand of air, when heated from the freezing to the boiling point of water; later researches, however, have shown that the true expansion of air within these limits is three hundred and sixty-six parts, or $\frac{1}{491\cdot2}$ of the whole for each degree of Fahrenheit's scale. Below the freezing and above the boiling point of water, the expansion is in the same ratio. A volume of gas measuring four hundred and ninety-one parts at 32° Fahr. expands, for every degree of heat additional, one part; so that at 60°—that is, with an increase of 28° of the thermometric scale—the volume becomes five hundred and nineteen parts. This ratio continues as long as the temperature rises, so that when the whole is heated to 523° = 32° + 491°, or in other words, is raised through as many degrees as there are original divisions in the bulk of the liquid, the volume will be doubled; and in proportion as multiples of this increase of temperature are applied, so will the air dilate to three, four, or more times its bulk. It was found, however, by Magnus and Regnault that the operation of this law is not perfectly uniform, especially with reference to the easily liquefied gases, which are more expansible than air when exposed to equal increments of heat, as the following table will show:—

	Expansion upon one volume from 32° to 212°.	
Names of Gases.	Magnus.	Regnault.
Atmospheric air,	0·366508	0·36650
Hydrogen,	0·365659	0·36678
Carbonic acid,	0·369087	0·36896
Sulphurous acid,	0·385618	0·36696
Nitrogen,	——	0·36682
Nitrous oxide,	——	0·36763
Carbonic oxide,	——	0·36667
Cyanogen,	——	0·36821
Hydrochloric acid,	——	0·35812

A sensible increase in the rate of expansion is also found when the gas is submitted to pressure, compared with that which takes place when it is in a rarefied state.

Conduction and Convection of Heat.—Another point of great importance is the comparative facility with which heat is conveyed or conducted through different bodies. When caloric comes in contact with solids or liquids, it enters into them and traverses from molecule to molecule, till it has permeated the whole. This property of heat, although by many supposed to be due to radiation, owing to the particles of matter not being in absolute contact, is, however, generally acknowledged to be due to a distinct action—that of conduction.

Different substances vary considerably in regard to the freedom with which caloric passes through them—that is to say, in their conducting power; and many very useful applications have been made of this property in the arts and sciences. It is upon this principle that nature protects every species of animal and vegetal life against the injurious influence of meteorological changes. The differences observed in the physical appearance of man and of other races of animals, according to their position on the globe, are ordered in conformity with the laws which regulate the conduction of heat; and the means adopted by various nations for shielding their persons from the opposite extremes of heat and cold, as also the covering of every indigenous species of living being, no matter of what class or kind, are all most admirably suited to the state and condition in which they live. The colored cuticle of the African, whose existence is ordained under a burning sun, is not less requisite for radiating or allowing a free passage for the heat he has to endure, than is the white skin of the European to prevent the sudden ingress and egress of caloric to or from the body. Not only does the natural state give proof of this wise disposition in the human species: it is still more manifest in the lower orders of creation, which have not like man the reasoning power that enables him to provide for the exigencies of his condition; hence they are usually defended by a non-conducting coat of fur or feathers, protecting them from sudden transitions of temperature.

Dense and heavy substances are generally good conductors; light and porous bodies have this property only imperfectly. This may be proved by taking metallic rods, to which small balls of wax are attached at different distances, and introducing one end of them into the flame of a candle. As the heat proceeds from one particle of the metal to another, its progress may be measured by the falling off of the balls successively, owing to the wax being melted by the heat. But if cylinders of wood, glass, or wax be heated in a similar manner, a different result will be observed, owing to the latter being bad conductors of caloric. A practical application of this fact is seen in metallic instruments intended to be used while hot; these are invariably furnished with handles of some badly-conducting material—such as wood or glass—to protect the hand from being scorched.

DESPRETZ instituted a series of experiments for determining the conducting power of metals. His method was to drill holes, at the distance of 3·93 inches apart, in bars of the metal of an equal and determinate thickness; into these holes thermometers were inserted, and the ends of the metals then applied to a heating medium. Caloric was allowed to traverse the bars as long as the thermometers continued to indicate an increase in the temperature. The observations made in this way furnished the annexed numbers:—

Gold,	1000·0
Silver,	973·0
Copper,	898·2
Iron,	374·3
Zinc,	363·0
Tin,	303·9
Lead,	179·6
Marble,	23·6
Porcelain,	12·2
Fire-clay,	11·4

Platinum is a singular exception to the general rule above stated; for, unlike silver, copper, or such other dense bodies, a wire of this metal may be held in the hand and heated to redness at one end, even when only a few inches in length. Glass, although a substance of moderate density, is likewise a bad conductor. The conducting power of a body is much diminished by its being pulverized; thus, metallic filings are worse conductors than bars of the same material; pounded glass and sawdust are also inferior in this respect to solid rods of glass or wood. Charcoal conducts heat very feebly; as also sand, and a number of other bodies, all of which on this account are of importance in cottage architecture, and for other purposes, in which it is desirable to provide against sudden changes of temperature.

The following are the results which Mr. HUTCHINSON obtained in his researches on the conducting powers of building materials. The substances are arranged in the order in which they resist the passage of heat, the best non-conductors being placed first:—

Name of substance.	Conducting power referred to that of slate, equal 100.
Plaster and sand,	18·70
Keene's cement,	19·01
Plaster of Paris,	20·26
Roman cement,	20·88
Beech wood,	22·44
Lath and plaster,	25.55
Fir wood,	27·61
Oak wood,	33.66
Asphalte,	45·19
Chalk—soft,	56·38
Napoleon marble,	58·27
Stock brick,	60·14
Bath stone,	61·08
Fire brick,	61·70
Painswick stone, H.P.,	71·36
Malm brick	72·92
Portland stone,	75·10
Lunelle marble,	75·41
Bolsover stone, H.P.	76·35
Norfal stone, H.P.	95·36
Slate,	100·00
Yorkshire flag	110 94
Lead,	521·34

Besides the use which is made of the property of non-conduction in architecture, there are other departments of the arts and manufactures in which it subserves important purposes. Thus it is applied with good effect in constructing fireproof edifices or apartments, and in the manufacture of chests and boxes intended to preserve valuable property, legal documents, *et cetera*, from the destructive effects of conflagration.

In the latter case, this is effected by interposing some solid body which is a bad conductor of heat between the interior lining and the exterior frame of the chest. The well-known safes of Milner and Son, of Liverpool, are constructed in this way. The inner chamber is made of stout sheet-iron, firmly secured by riveted bolts to the exterior one, which, by its strength, is calculated to resist fire, and any external violence, either intentional or accidental, to which it is liable. The intermediate chamber is filled with a composition which can scarcely be excelled as a non-conducting material, whilst, at the same time, its heat-absorbing power, or, in other words, its quality of rendering heat latent or insensible, is very great. From repeated testings, at some of which the Editor attended, these articles have been proved capable of withstanding a twenty-four hours' fire of intense heat without allowing the contents to be injured in the least. Fig. 2 is a front view, and Fig. 3 a section of one of these safes. In Fig. 3, the chamber containing the non-conducting material is shown. At one time this consisted almost entirely of clay, sand, and some carbonaceous matters, in the middle of which were metallic tubes filled with water, and hermetically sealed with a fusible alloy. When the heat reached them, the plug of metal by melting allowed the water to flow out, thus moistening the ingredients, and arresting the passage of the caloric. If the fire were prolonged, the moisture would be disseminated in vapor in the inner chamber where the valuables were deposited, and thus would secure them still more perfectly against combustion. The tubes, however, were found troublesome and expensive, and improvements of a simpler nature adopted. According to the specification of Mr. Milner, the ingredients now used are quartz, crystallized carbonate of soda or alum, and the dust of hard woods, all of which are blended in such proportions as that twenty-five per cent. of the whole shall consist of moisture, which is capable of being expelled on the application of heat. The water in this case is exclusively derived from the salts—the carbonate of soda containing sixty-two and the alum fifty-five per cent. of water, which is separated slowly even with the application of a very high temperature.

Fig. 2.

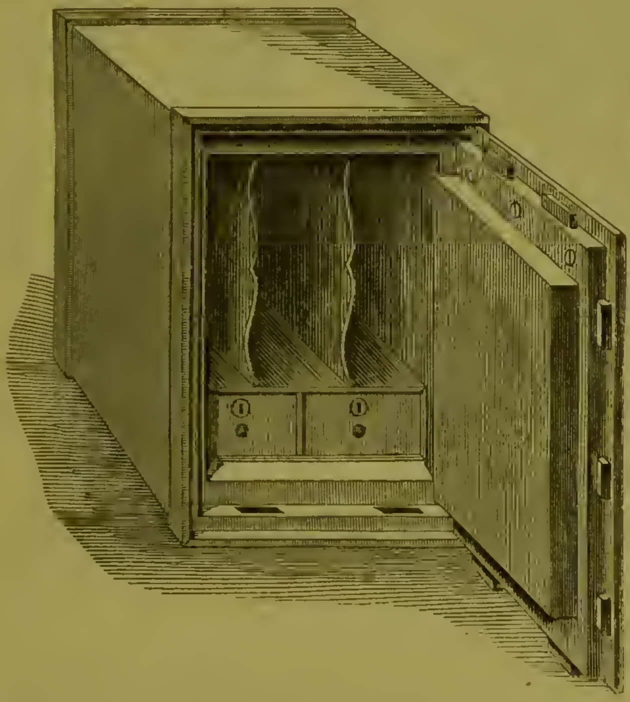
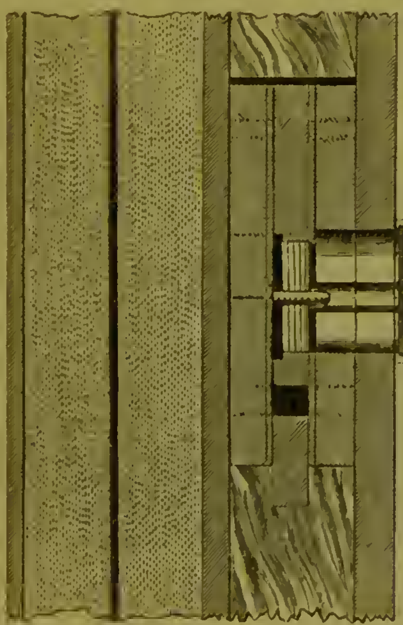


Fig. 3.



The same principle is brought into requisition when the design is to preserve the heat in rooms and prevent it from escaping. In this case, the object is accomplished by constructing double doors and windows: thus enclosing a partition of air, which is a very imperfect conductor of caloric, and, therefore, the heat of the chamber is retained. In a similar manner, fireproof chambers may be made, having, in connection with the space between the double walls, a means for supplying cold air to occupy the place of that which must pass off as the increased temperature expands it. Unless such provision be made, the pressure which the increased tension of the vapor acquires as the heat increases would be apt to burst the walls.

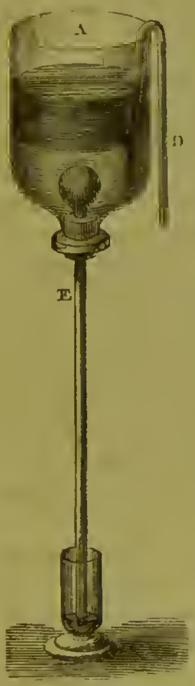
On similar principles great attention is required in selecting the materials employed in the construction of furnaces. To prevent the escape of the caloric, and thus to economise fuel, the hearth and walls of the furnace are invariably compounded of some non-conducting substance, as Stourbridge clay or powdered brick, mixed with a large quantity of powdered charcoal or coke. For the same reason, boilers are imbedded in bricks or clay, and in many boilers the fire is literally enclosed within them, that none of the heat may be lost, but that all may be rendered available for raising the temperature of the water.

Seramont examined the conducting power of crystalline bodies, and proved that, in such as do not belong to the regular system, power varies in different directions according to the inclination of the optic axis of the crystal. De la Rive and Decandolle have, in like manner, shown that the conducting power of wood is different according to the direction in which the heat is transmitted, being greatest in the course of the grain or fibre, and least across it. Tyndall has established the same fact by showing that caloric much more readily traverses from the surface of a log of wood to the centre, than it does in a direction parallel to the annular layers of ligneous matter. In woods, also, as in metals, their conducting power appears to vary with their specific gravity, being least in the lightest kinds; this, however, requires corroboration. Textile fibres which are manufactured into articles of clothing are very bad conductors; but their actual conducting power cannot be exactly ascertained, in consequence of the air which is contained in their pores.

Liquids in general are bad conductors of heat; it was formerly asserted, indeed, by some chemists, that water is an absolute non-conductor; it has been proved, however, that liquids conduct caloric in some measure, subject to the same laws as solids, although, as regards water and other such mobile liquids, very feebly.

The following experiment, among many which might be adduced, will illustrate the weak conducting power of water:—

Fig. 4.



Let the mouth of a bottomless glass jar, A, be closed by a perforated cork, through which the stem of an air thermometer, E, passes. Invert the jar, and pour into it cold water till nearly half-filled; on the surface of this cold liquid, place a cork disc, and then introduce a quantity of warm water colored either red or blue, to distinguish the two portions of liquid. The disc may now be cautiously removed, and the hot water will remain in a distinct layer upon the other. If the heat were conducted through the cold medium, it would act upon the air thermometer by causing the expansion of the enclosed air, and the expulsion of a proportionate quantity of the liquid from the stem; but no such effect is observed. If the cold water be now drawn off from the bottom by means of a siphon, D, it will still be found that no rise of temperature is indicated by the instrument, till the colored liquid comes in contact with the bulb, when the confined air will be expanded, and the tinged liquor in the stem ejected into the vessel into which the thermometer dips. From this it is evident that the conducting power of water is very feeble, and so with other similar mobile liquids. If, however, mercury be substituted for the cold water, and the warm water poured upon it, the effect upon the thermometer is instantaneous. This proves that fluidity is not the cause of the non-conduction of heat by water, and other similar bodies, but that it depends to a certain extent on the nature of the substance itself.

Moreover, the effect observed is very different when, instead of applying caloric at the upper surface, it is communicated to the under part, or to the bottom of the vessel in which the liquid is contained. In this case, the particles in immediate contact with the heat-giving body acquire a portion of caloric, and are expanded. This, by rendering them lighter than the surrounding ones, causes them to ascend; fresh particles succeed, and these rise in a similar manner. Currents are thus determined in the liquid, and caloric is readily communicated to the whole mass. This, however, is not a case of conduction from particle to particle; neither is it due to radiation, which will be afterwards explained; but is the effect of *convection*—that is to say, the actual conveyance or distribution of the heated portion throughout the mass.

Fig. 5.

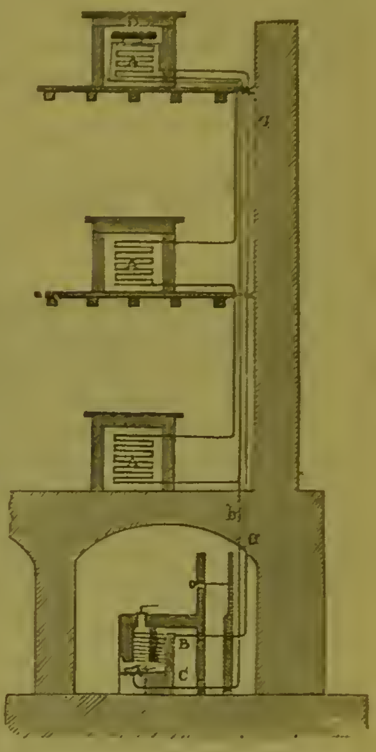
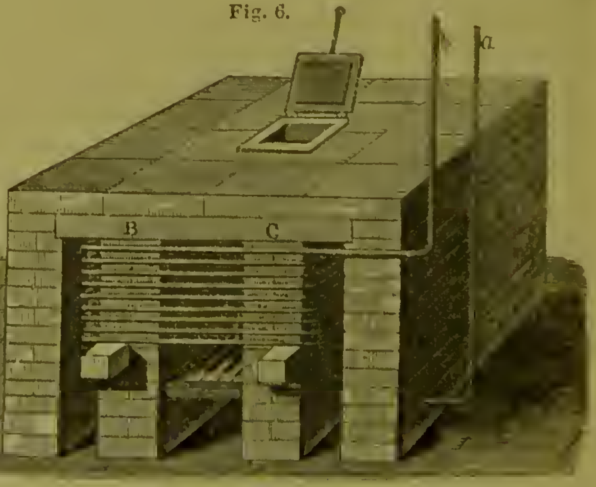


Fig. 6.



Very great benefits are derivable from this property of fluids. It has been advantageously applied in the ventilation of buildings, the hot air rising to the top and escaping, while cool air is injected. It is upon this principle also that Perkins's apparatus for the heating of dwellings is constructed. This is represented in its simplest form in Fig. 5; it essentially consists of an iron pipe one inch in exterior diameter, and half an inch in the bore. This being filled with water and distributed throughout the building, a portion of it is heated in a furnace, and a current is thus established through its entire length. The caloric acquired by the water in its passage through the heated portion of the pipe, is given off by radiation in performing the rest of the circuit, till it returns to be reheated. The several coils, A A A, may represent as many apartments, each embracing a considerable length of pipe; the coil, B C, which is generally about one-sixth of the whole length, and which is represented on a larger scale in Fig. 6, receives the heat of the furnace. The course of the water from this portion is through the pipe. *a a*, which rises till it reaches to the top of the building; here it branches off into several conduits to traverse the different parts of the edifice, all reuniting in the pipe, B, before returning to the furnace. Water is introduced at the open end, D, which is kept tightly plugged while the apparatus is in action; a space, E, is provided in connection with the pipe at the top of the building, to admit of room for the expansion of the heated liquid, and thus prevent the bursting of pipes: its capacity is about one-fifth or one-sixth of the whole.

Apart from the consideration of the useful purposes to which the convection of heat is applied in the arts, a far more important end is served by it in the economy of nature. During the frosts of winter, the process of cooling goes on downward from the surface of the earth and water. The colder water at the top becoming condensed, and consequently heavier than that beneath, sinks and gives place to the latter; this goes on as long as the atmosphere remains at a low temperature, till the water is reduced to its maximum density, a point which it attains at 39·4°. It is a remarkable circumstance, and forms a singular exception to a general law, that water when cooled to this point begins to expand, and consequently remains at the surface. When cooled to 32° it freezes, and during its conversion into ice it experiences a still further expansion, so that the ice, instead of sinking to the bottom, and there accumulating in dense masses, floats on the surface till melted—one of the most wonderful provisions for the preservation of life in the whole economy of nature.

In their mode of conducting heat, gases resemble liquids; that is to say, their power of actual conduction is inappreciable; but by their property of convection, currents are instituted by which the heat is disseminated throughout the mass. To observe this, it is only requisite to hold the hand first at the side of a lighted candle, and then above it, the distance in both cases being equal; it will be perceived that, in the first position, little heat is received, whilst in the second the increase of temperature is immediately obvious, the greater portion of the heat being carried off in the ascending current; which, in gases, is more active than in liquids, owing to their power of expansion being so much greater. The application of these currents of heated air is of great practical importance in the ventilation of dwellings and public buildings. Indeed, in every species of human habitation, provided with a fire-place and chimney, the latter operates as a ventilating apparatus. The heat derived from the combustion of fuel in the grate or on the hearth, dilates the super-imposed atmosphere, and causes its ascent in the shaft, while an influx of air to the fire supplies its place. The transmission of smoke and warm air through the chimney soon raises its temperature, and, on this account, the heat which is received from the fire is retained by the vapor till it passes out at the top. The force of the current or *draught* thus formed will be in proportion to the greater expansion of a column of air of the height of the chimney, than that of an equal column externally. Common air, like other gases, increases one five-hundredth of its bulk for each degree of temperature which it acquires; hence, by ascertaining the internal temperature and height of the chimney, the force of the ascending atmospheric column may be calculated. When it happens that the apartment is very close, and does not admit sufficient air to supply a stream from beneath, it enters at the top of the shaft, and causes a *back* draught. In such cases the chimney is said to smoke, and the remedy usually applied is to open the door or window, so as to admit sufficient air to maintain the current. To avoid smoke, care should be taken in hanging the doors, *et cetera*, that space be allowed for the influx of air, so as to prevent its entrance from above. It is a well-known fact, that in a heated apartment the warmer portion of air rises to the ceiling, and the colder stratum remains underneath; hence it is obvious, that to maintain a proper state of ventilation, apertures must be provided in or near the ceiling, whereby the warm gases may escape. This, however, will prove ineffectual, unless provision be made for the entrance of a corresponding volume of air at or near the floor, to supply the place of that expelled. In large buildings, where the heat eliminated from fires would be ineffectual towards warming them, heated air is used in nearly the same way as the water in PERKINS'S method, only that the hot air is distributed in the various apartments through gratings in the floorings or side walls. Dr. REID'S apparatus for ventilating St. George's Hall, Liverpool, operates in this way; and several other large enclosures and churches throughout the kingdom are heated on the same principle. The phenomena of winds and oceanic currents are all referrible to the same cause; and, as in the case of ventilating apparatus, so on the large scale of the globe, the streams or currents which are induced by differences of temperature tend to equalize the amount of heat which is received from the sun, to distribute it more uniformly over sea and land, and thus to modify the intensity of cold and heat in climates exposed to opposite extremes of temperature.

RADIATION OF HEAT.—On the whole, it may be laid down as a general law, that air, the gases, water, and fluids generally, with the exception of mercury, are bad conductors of caloric, notwithstanding that it is distributed readily by them in the manner already explained. Although, however, it is the natural tendency of convection to operate upwards, yet, if the hand or the bulb of a sensitive thermometer be placed at some distance beneath a warm body, or on either side of it, an increase of heat will be indicated. From this it is evident, that though the permanent gases and the atmosphere do not sensibly conduct caloric, yet, in common with liquids and other transparent bodies, they permit its passage without being themselves appreciably affected by it. All the caloric received by the earth from the sun—the amount of which, to each acre in the latitude of London, is calculated by FARADAY to be equivalent to that which is generated by the combustion of sixty sacks of coal—thus travels through the intermediate space of ninety-five millions of miles, without sensibly affecting the temperature of the atmosphere, or that of the subtle medium beyond it. When heat emanates from any body in this way, it is said to be radiated from it, and the imponderable itself is denominated *radiant heat*. Thus, if a bar of heated metal be suspended in a room for some time, the excess of caloric contained in it will pass off in all directions, and the metal ultimately indicates only the same temperature as the surrounding objects. During the cooling, the heat passes off at all points of the body in direct lines as from a centre—hence the term *radiated.* To prove that convection and radiation are distinct processes, and that the latter is not a consequence of the former, all that is necessary is to expose a heated body in the vacuum of an air-pump, in which case it will be observed that the emission of caloric is much quicker even than if it were allowed to cool in contact with the air.

In simple language, the rate of cooling expresses the radiating power; and Leslie ascertained that the radiating power of bodies was more influenced by the state of their surface than by the nature of the material. A bright tin globe filled with water at a certain temperature was allowed to cool, and the time being carefully noted, it was found that the contents of the vessel cooled half way to the temperature of the room, in one hundred and fifty-six minutes. When the same experiment was repeated with the surface of the globe coated with lamp-black, it was observed that the mercury in the thermometer fell through the same space as it did in the first experiment in eighty-one minutes: thus showing, that by the alteration of the surface the radiating power was doubled. Count Rumford corroborated this observation by another experiment. Taking two brass cylinders of equal size and capacity, and investing one of them tightly with linen, while the other was left bare, he filled the two with boiling water, and allowed them to cool. During this process, he observed that the coated cylinder lost 10° of its original temperature in thirty-six minutes and a half, while the other required fifty-five minutes to pass through an equal range. Hence may be deduced the important practical inference, that liquids are best kept warm in highly polished vessels, and that it is an error to wrap them round with cloths or other coverings, which radiate the heat more rapidly than polished metals.

By following the method of Leslie and Count Rumford in the foregoing experiments, namely, coating the heated surface with various materials, and observing the time required in cooling, or, as will be presently noticed, by concentrating the rays radiated from a certain extent of surface, and ascertaining their intensity by their action upon a delicate thermometer, the comparative radiating power of different bodies may be ascertained. By this method it has been found that lamp-black is superior in radiating power to any other substance hitherto submitted to experiment, and that if this be represented by 100

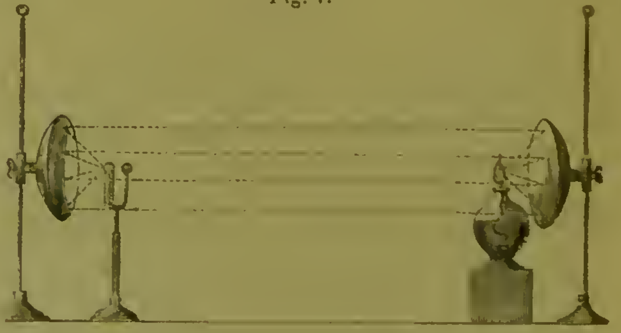
Writing paper will be......................	98
Resin,......................................	96
Sealing wax,.	95
Crown glass,.................................	90
Indian ink,..................................	88
Ice,...	85
Isinglass and red lead, ...	80
Plumbago,....................................	75
Tarnished lead.	45
Polished lead.	19
" tin plate, gold, silver, copper,....	12

From this table it will be seen that lamp-black irradiates five times as much of the caloric of boiling water as clean lead, and eight times more than bright tin. The general low radiating power of the metals is increased if these be allowed to tarnish, as exhibited in the case of lead in the preceding table. Smoothness of surface, however, does not always act in relation to other bodies as it does in metals, for glass and porcelain, although their surface is smooth, always radiate very powerfully. When the actual radiating surface is metallic, it is not affected in a sensible manner by the substance under it; thus glass, coated with gold leaf or tinfoil, possesses the radiating power of the superimposed metals.

In general, the rapidity of cooling of any body depends upon the excess of its temperature over that of the external air; the hotter it is, the more freely does it give out caloric in a given time, and, as its temperature sinks, the longer is it in parting with the excess. Dulong and Petit found that the rate of cooling differs according to the nature of the atmosphere surrounding the heated bodies; they also observed, whilst making experiments upon bodies in vacuo, that if they acquired heat in an arithmetical ratio, the same would be radiated in a geometrical one.

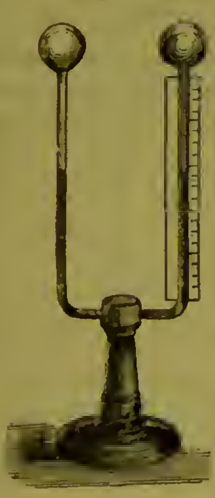
Radiant heat is absorbed, reflected, or transmitted, according to the nature of the body on which it impinges; and the absorption, reflection, or transmission is in every case governed by peculiar laws. Polished metallic surfaces reflect the greater portion of the heat which falls upon them; and the incidental and reflected rays are in the same plane, and make equal angles with the reflecting surface. If two concave metallic mirrors be placed directly opposite to each other at some distance, and a lighted candle be fixed in the focus of one of them, the rays of heat received by the latter will be found reflected to the opposite mirror, where, instead of being absorbed, they will be further reflected and concentrated in the focus of this one: and, if a delicate differential thermometer be placed at this point, the quantity of heat thus concentrated may be registered. Such was the method adopted by Leslie, Melloni, and others, in their researches upon heat, as shown in the annexed engraving, Fig. 7. In this case the reflectors, if thoroughly polished, do not acquire a perceptible increase of temperature, nor indeed do any of those bodies which throw off by reflection the rays of heat incident upon them. It is only when the reflection is incomplete, either from the nature of the body or the want of a sufficient polish, that heating of the mirrors takes place. If in the above experiment a reflector of glass were

Fig. 7.



used instead of one of metal, only a very small portion of the calorific rays would be reflected, the greater part being absorbed by the disk, which in consequence would readily indicate a higher temperature; but by coating the surface of the glass with gold leaf or bright tinfoil, it will then became a polished metallic mirror, capable of powerfully reflecting the calorific rays. By experiments such as these, **Leslie** demonstrated that the reflecting power of a body is chiefly dependent on the nature and condition of its surface, and that those qualities which are adverse to radiation are such as promote reflection. Bright smooth metallic surfaces, such as polished silver, brass, or steel, which are strongly retentive of their own heat, are little prone to receive it from other sources, but cause its reflection in the same plane, and at an angle equal to that at which it strikes the surface. It is to this circumstance that the Dutch oven and meat screen owe their great efficacy in culinary processes.

Fig. 8.



The *differential thermometer* or *thermoscope*, to which allusion has been made in the preceding passage, and which is represented in the last figure in the focus of the left-hand reflector, is shown on a larger scale in Fig. 8, and consists of two bulbs, A and B, containing air, united by a tube twice bent at right angles, in which there is a little colored sulphuric acid. This is essentially an air thermometer, from which the atmospheric pressure is excluded. When heat is applied to one of the bulbs, the air within it expands, and draws the fluid towards the other, when either its depression or elevation, showing the amount of the expansion, may be read off on the scale. It is evident that this instrument cannot be employed to indicate general changes of temperature in the surrounding medium. It is not affected by such changes, which act equally on both bulbs; but when one of these is exposed to any source of heat which does not affect the other, as when it is placed in the focus of a reflector, the *difference* of temperature between the two bulbs is immediately and very sensibly indicated by the recession of the fluid from the heated towards the cold bulb. The *thermopile*, an instrument still more sensitive to slight changes of temperature, will be described immediately.

Melloni performed a number of experiments with the view of ascertaining the comparative absorbent power of certain bodies for caloric. He employed a variety of heat sources of different degrees of intensity, and fixed the ball of a thermoscope coated with lamp-black at such a distance from each, that the liquid contained in it recorded the same degree of temperature in every instance. The distance being marked, the ball was removed and coated with other substances instead of lamp-black, and then successively exposed as before to the action of the heat radiated from different sources. The results showed a remarkable variation, according to the source of the caloric. Thus, when the ball was coated with white-lead and exposed to the rays from the flame of an oil lamp, it indicated only 53; but when red-hot platinum wire was substituted for the flame of the lamp, it was found to be 56; with a copper plate, it indicated 89; and, when exposed to a canister of boiling water, it registered 100. In each of the preceding cases, however, the thermoscope when blackened exhibited 100. The subjoined tabulated results, showing the relative absorbability of different kinds of heat, were obtained in this manner :—

Thermoscope coated with	Naked flame from oil lamp.	Incandescent platinum.	Copper at 750°.	Canister of water at 212°.
Lamp-black, ...	100	100	...... 100	100
White-lead, ...	53	56	...... 89	100
Isinglass, ...	52	54	...... 84	91
Indian ink, ...	96	95	...... 87	85
Shell-lac, ...	43	47	...... 70	72
Polished metal,	14	13·5	...... 13	13

With regard to the heating of bodies by radiation, **Knoblauch** has shown that the effect produced when the radiated heat is *intensified* is totally independent of the temperature of the source, and is determined only by the nature of the absorbing bodies, which receive certain rays more readily than others. This was proved by coating one side of a sheet of metal with lamp-black, one half of the reverse being covered with carmine, and the other with black paper, and exposing the latter alternately to the action of an argand lamp, and a metal cylinder raised to 212°, while the side covered with lamp-black was turned towards the thermopile. With this arrangement the following resnlts were obtained :—

Sources of heat.	Direct radiation.	Interposed Carmine.	Black paper.
Argand lamp, ...	35	9·50	10·75
" "	50	13·75	15·25
Cylinder heated to 212°, ...	35	10·87	10·12
" "	50	15.62	14·00

To determine how far the thickness of bodies affected their heating by radiation, he used a metal plate coated with layers of varnish :—

Sources of Heat.	Direct Radiation.	METALLIC PLATE										
		Naked.	Covered with									
			Layers of Varnish.				Layers of Black Lac.				Layers White Lead.	
			1.	2.	4	8.	Thin.	Thick.	Thicker.	Thickest.	Thin.	Thick.
Argand lamp, ...	35°	6·50°	8·25°	8·25°	8·25°	8·25°	7·12°	8·25°	8·62°	9· 5°	7·25°	8·00°
" "	60°	10·50°	14·50°	15·12°	15·62°	15·75°	14·50°	16·25°	17·37°	18·12°	16·12°	18·50°
Metal cylinder heated to 212°,	35°	6·50°	9·00°	9·25°	9·50°	9·50°	9·12°	9·87°	11·62°	12·00°	8·75°	9·62°
" "	60°	10·50°	17·50°	17·50°	20·12°	20·75°	18·62°	20·25°	21·37°	20·17°	17·00°	19·50°

From these results it appears that the substances employed are more strongly heated in proportion as their thickness is greater, within certain limits. Melloni and Leslie arrived at a different conclusion, in consequence of having used plates of such thickness that only a small proportion of the heat absorbed could penetrate to the side which was turned towards the thermoscope; Knoblauch, on the contrary, employed media, the thickness of which was not too great to allow each successive layer to be heated, and thus to act upon the metallic surface.

Fig. 9.

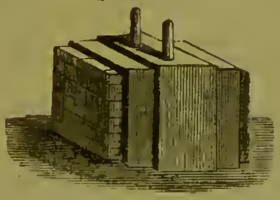
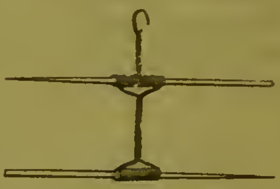
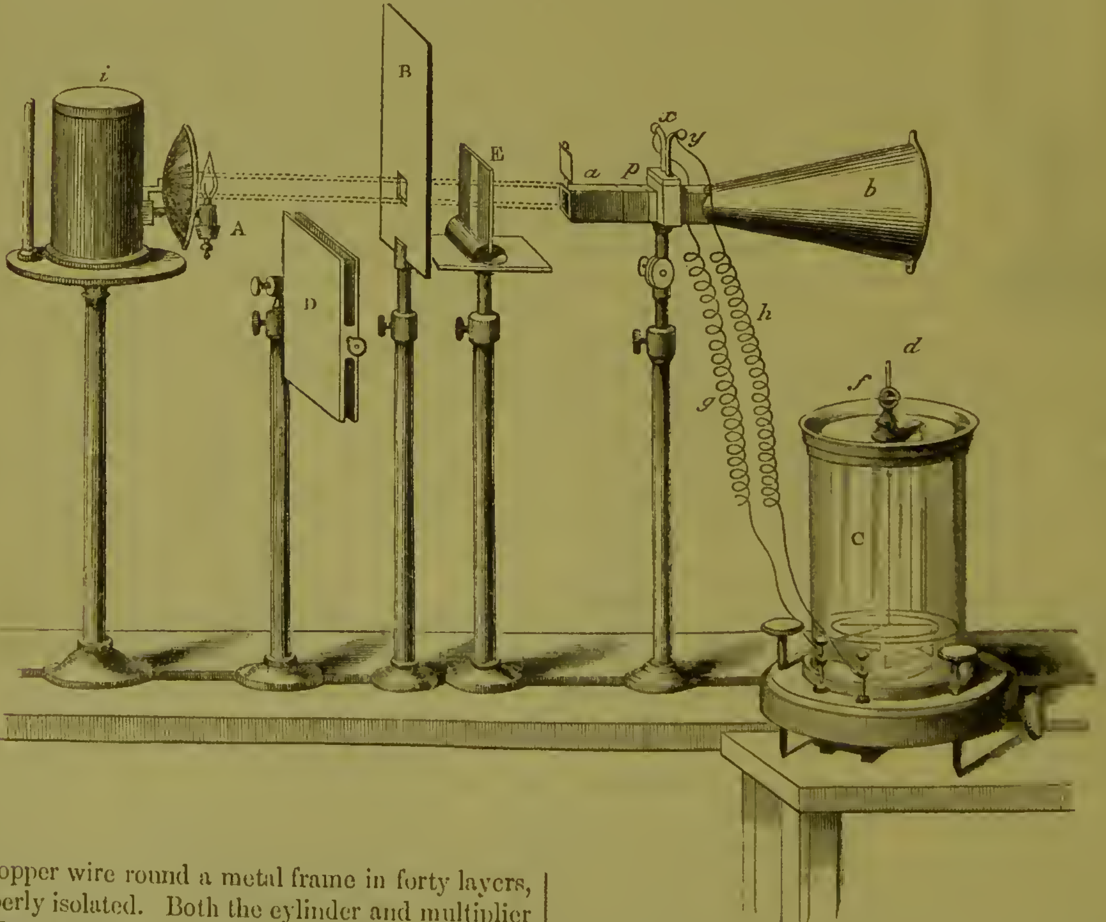


Fig. 11.



The Thermopile.—Melloni found that caloric was transmitted by many bodies which were impervious to light, and these he termed *diathermous* or *heat-transmitting*, in contradistinction to *diaphanous* or *transparent* bodies. In conducting his experiments on this subject, he employed, in connection with a very delicate galvanometer, an instrument which he termed a thermopile. This consisted of a number of pairs of bars of bismuth and antimony joined together, and so enclosed in a cylinder—see Fig. 9—that by turning one end of the latter towards the region whence the heat is radiated, it would fall upon the alternate points of junction of the bars of metal, and excite, as is well known, a current of electricity, the intensity of which is in proportion to the amount of heat received. By wires connecting both ends, *x* and *y*, of this battery with the galvanometer, the electricity was measured; and thus was obtained a ready and delicate method of estimating the amount of heat transmitted. Fig. 10 shows this arrangement, in which the pile is introduced. Both ends of the bars are blackened with soot, in order that the absorption of the rays of heat falling on them may be the more complete. By means of screens, *a* and *b*, the pile is preserved from the effects of currents of air; *b* has a conical shape, and is intended to concentrate the rays of heat when very feeble on the end of the pile. The pile is firmly bound, as represented at *p*, and fixed to a sliding stand in a perfectly horizontal position. *x* and *y* are bars in connection with the opposite ends of those of the pile, to which the wires *g* and *h* are screwed at one end, the other being in connection with the helice of coated wire that serves to act upon the galvanometer at *m* and *n*. The galvanometer is composed of a carefully selected and well magnetized pair of needles, bound together with fine copper wire, as seen in Fig. 11, and freely suspended in the middle of a glass cylinder, C, by a single fibre of silk which is attached to a ball, *f*, by turning which the needle may be raised or lowered at will. The helice, or multiplicator, in the midst of which the needles are suspended, is constructed by winding coated copper wire round a metal frame in forty layers, and properly isolated. Both the cylinder and multiplier are fixed to a table, so that when the needle hangs freely from *f*, it will rest in the centre of the closely divided circle, pointing to zero in the plane of the magnetic meridian. When the pile and multiplier are connected, the least change of temperature that may

Fig. 10.



affect the ends of the compound metals deflects the needle, and the amount of this deflection may be noted on the divided circle. When working with this instrument, the first deviation of the needle must be carefully distinguished from the proper angle of deflection—*id est*, from the angle which it makes with the magnetic meridian, when unaffected by any electrical currents. If the equilibrium of the galvanometer is disturbed by a stream of electricity, it returns from the point to which it has been deflected, with a certain degree of velocity, which causes it to go beyond zero; it will oscillate thus for some time before the stationary line is attained. To avoid the delay which these oscillations would occasion, Melloni ascertained by experiments the ratio between the first and final deflection—*id est*, he determined how large the final deflection is that corresponds to the original one. The knowledge of this relation offers great advantages, inasmuch as each experiment lasts only ten or twelve seconds, whereas, if the operator had to wait till the needle became stationary, several minutes would be required.

If the principle of the apparatus comes to be considered, it will be evident that the relation which exists between the difference of temperature of the soldering points of the pile and the deflection of the needle cannot be ascertained in an absolute manner. To give the deflection a definite value as to the amount of caloric, Melloni had to determine—after establishing the fact, that the strength of the electric stream from a pile of bismuth and antimony is proportional to the difference of temperature of the soldering points—the relation of the deviation of the needle to the strength of the stream. For this purpose, he placed at either end of the pile a constant source of heat—such as a Locatelli's lamp—at such a distance, that when working alone at one end it caused a deflection of about 40° to the right, and, when placed at the other, the deflection marked 35° to the left side; but, when the sources of heat were permitted to operate on both ends at once, the deflection to the right marked 15°. From this behavior it was inferred that the difference between 40° and 35° corresponded with 15° counted from 0°. By operating in this way, it may easily be understood how, by changing these experiments, a table may be constructed, the first column of which expresses the observed deflection, and the second the corresponding number of degrees which would be arrived at if the deviation were proportional to the strength of the stream, and the action of the latter on the needle were not the weaker the more the latter is deflected. With the apparatus employed by Melloni, the numbers on both columns up to 20° were equal—that is to say, till 20° the deflection of the needle is proportioned to the strength of the stream; but with the observed deflection, 25, 30, 35, 40, and 45°, correspond the value 27, 35, 47, 62, and 83° of the second column. A stream, therefore, that produces a deflection of 40° is 62 times stronger than another that causes only a variation of one degree. Melloni so arranged his experiments that the deflections were always less than 30°.

To return to the manner of working the apparatus: if the body emitting rays of heat be fixed in the focus of a reflector that impels the rays of heat in a horizontal line with the pile, and one of the ends of the latter be exposed to them, the effect upon the needle will, upon the principles already laid down, be indicative of the quantity of radiated heat. When different sources of caloric are thus presented in succession, the register of the deflection of the galvanometer will show the difference of radiation.

Transmission of Heat through Thin Plates.—The bodies employed by Melloni were a Locatelli's lamp, fixed as at A in Fig. 10; a coil of platinum kept at incandescence by the flame of alcohol, as seen in Fig. 12; a blackened copper foil fixed to a stand, and heated with a spirit lamp to 752°, as represented in Fig. 13; and a brass canister filled with water kept at 212°, as shown in Fig. 14. One or other of these was placed on a movable support, as at A, behind the perforated screen, B, the rays being concentrated when necessary by the reflector at A, and received at a certain distance from this upon the thermoscope. The sensitiveness of the latter was proved by placing a double screen of polished copper, D, between it and the source of heat, so as to intercept all the calorific rays, and observing the deflection of the needle of the galvanometer in C, when the screen was removed. The elevation of temperature produced by the direct action of the radiating body being thus known, the substance to be examined was then introduced in the place of the screen, as at E. By observing the difference of temperature as indicated by the needle now, and comparing it with the effect produced without the screen, the proportion of heat transmitted by any interposed body was at once ascertained. By this method, Melloni found that plates of rock-salt of great transparency, and varying in thickness from one-twelfth of an inch to two or three inches, transmitted ninety-two out of every hundred rays of heat which fell upon them, no matter from what source derived. As the remainder of the rays were found to be reflected from both surfaces of the plate, it may hence be concluded that what the colorless plate of glass is to rays of light, the plate of rock-salt is to those of heat. Sometimes the calorific rays which pass through one body are intercepted by a plate of another body, or by another plate of the same. In experimenting upon this, Melloni found that the caloric which has passed through one plate of glass, becomes less subject to absorption in passing through a second and a third plate of the same material. Thus, of one thousand rays of heat from an oil lamp,

Fig. 12.

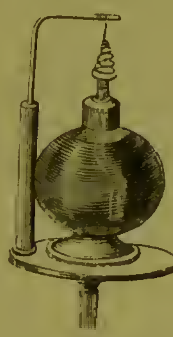


Fig. 13.

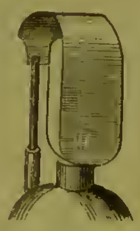
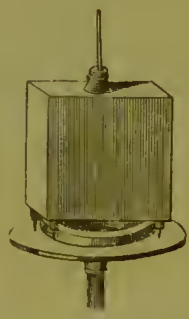


Fig. 14.



four hundred and fifty-one were intercepted in passing through four plates of equal thickness, and—

Of these the first plate intercepted	....	381
" the second "	....	43
" the third "	....	18
" the fourth "	....	9
		451

It was found by Delaroche that the higher the temperature of the source of heat, the greater in proportion to the whole is the quantity which passes through a plate or screen of glass. He observed that from a body heated to 182° only one-fortieth of the whole permeated, whereas when the temperature was 346° the one-sixteenth passed through, and when the heat was raised to 960° Fahr. as much as one-fourth of the whole amount of heat was transmitted. To show the independence of diathermacy and translucency, Melloni took a blackened ball of copper heated to 400° Fahr., and placing it midway between the blackened bulbs of two thermoscopes so that they might receive an equal amount of heat, noted the effect; then fixing between the ball and the instruments for measuring the heat plates of rock-salt and glass of equal thickness, it was quickly observed that the temperature of the bulb behind the former was much more elevated than the other—thus showing that more heat passed through it than through the glass one, although in transparency they were equal. In liquids this independence is still more manifest. Thus, out of one hundred rays that fell from an argand lamp on each of four fluids equally transparent—namely, water, oil of turpentine, ether, and sulphuric acid—the number of rays of heat transmitted were :—

Water......................	11
Sulphuric acid	17
Ether	21
Oil of turpentine	31

The following is a tabulated statement of some of the results ascertained by Melloni on the subject of the transmission of heat through various bodies of equal thickness :—

Name of the interposed substance. Common thickness 0·102 inch.	Transmission of 100 rays of heat from			
	Naked oil flame.	Red-hot platinum.	Copper at 732° F.	Copper at 212° F.
Rock salt, transparent and colorless,	92	92	92	92
Sicilian sulphur, yellow,..........	74	77	60	54
Fluor spar, limpid, ...	72	69	42	33
Rock crystal, cloudy, ...	65	65	65	65
Beryl,...........................	54	23	13	0
Flint glass,......................	67	—	—	—
Plate glass,......................	39	24	6	0
Iceland spar,.....................	39	28	6	0
Rock crystal, limpid, ...	38	28	6	0
" brownish, ...	37	28	6	0
Tourmaline, dark green,..........	18	6	3	0
Citric acid,......................	11	2	0	0
Alum, ...	9	2	0	0
Sugar candy, colorless, ...	8	1	0	0
Fluor spar, ...	8	6	4	3
Ice, transparent and colorless,.....	6	0	0	0

Similar experiments being performed with liquids contained in glass, the stratum being 0·362 inch in thickness, and the source of heat being in each case flame from an argand oil-lamp, the annexed results were obtained :—

Bisulphide of carbon,......................	63
Bichloride of sulphur, red-brown..........	63
Terchloride of phosphorus,................	62
Essence of turpentine,....................	31
Colza oil, yellowish,......................	30
Olive oil, greenish,.......................	30
Ether,....................................	21
Sulphuric acid, colorless, ...	17
" brown,.....................	17
Nitric acid, ...	15
Alcohol,..................................	15
Distilled water,...........................	11

The fact that bodies which are pervious to light do not maintain the same relation to heat, is best exemplified by sulphate of copper, which permits the passage of blue light abundantly, but absolutely intercepts caloric. On the contrary, the opaque glass which is used for polarizing mirrors, allows the thermal rays to pass, but quite intercepts the light; and smoked rock-salt and black mica act in a similar way. Radiated heat is not only transmitted, but refracted in the same manner as light. This is proved by the well-known property of convex lenses or *burning glasses*, which concentrate not only the light, but the rays of heat, in the focus. Caloric further resembles light in apparently consisting of rays which possess different degrees of refrangibility, as may be proved by subjecting a beam of light to the action of a transparent prism of rock-salt, and examining the spectrum so obtained by means of a delicate thermometer. In this case it will be found that the heat varies at different parts of the spectrum; and experiment has shown that when the rays of the sun are operated upon, the most part of the rays of heat are less refrangible than even the red light; the maximum temperature being found at some distance below the extreme red. The refrangibility of the rays varies with the source of heat; the higher the temperature the greater is the refraction. For example, the rays of heat emitted from an argand lamp are refracted all over the spectrum, but the maximum intensity is about the middle; from ignited platinum the maximum falls nearer to the red: from copper heated to 750°, nearer still; and so on till the temperature of the source cools to 212°, when it is found to emit scarcely any of the more refrangible rays.

Specific Heat.—Bodies have different capacities for heat; or, in other words, the application of the same amount of caloric will elevate the temperature of different bodies unequally. This capacity for caloric, differing in different bodies, is termed their *specific heat*. If a certain weight of water, at the ordinary temperature of the atmosphere, be mixed with an equal quantity of this liquid raised to a higher degree, the mixture will indicate a mean between these extremes; but if another liquid, such as oil or mercury, be added, instead of the second portion of water, a great difference will be observed. When a measure of water at 60° Fahr. is agitated with as much mercury at 140°, the compound, instead of marking 100° as in the preceding case, will indicate only 86·6°. Again, if mercury at 40° be added to an equal bulk of water at 156°, the heat of the latter is reduced by 3·7°, which, being absorbed by the fluid metal, raises it to 152·3°, so that each degree which the water indicates by the instrument has the effect of 30·35° upon the fluid metal. Taking, then, the capacity of water for heat to be unity, that of mercury will be found from the above results to be 0·033. The capacity of any other body for heat may be determined with tolerable accuracy in the same way; the sides of the vessel, however, are liable to radiate more or less caloric, and will, of course, cause a slight deviation from absolute accuracy in the results.

Many plans have been proposed for estimating the capacity of bodies for heat. The method just described was followed by Wilke, Crawford, Kirwan, Dalton, and others; whilst Delaroche, Berard, Neumann, and Regnault proceeded on the principle of allowing equal weights of bodies to be exposed to the same cooling medium, and observing the difference in the time which they required to fall to the same degree; or, inversely, the time was noted which the bodies, when subjected to the same temperature, required to arrive at the marked degree. The difference, of course, depended upon the capacity for caloric, and from this datum the latter was relatively estimated. Lavoisier and Laplace endeavored to arrive at more correct results, by ascertaining how much ice the body dissolved in cooling down to the freezing point; but this method was likewise liable to error, for the ice retains a portion of water which has been liquefied, and, therefore, the measurement of the quantity dissolved cannot afford a perfectly correct estimate; besides, portions of what has been rendered fluid are liable to be frozen again, and in either case the results must be incorrect. Dulong and Petit conducted their researches by allowing spheres of equal size, equally heated, to cool, and noting the time which they required to fall to a given point; this, of course, will depend on the relative amount of heat which they contain, provided the radiation is rendered equal. The capacity of bodies for caloric is expressed by *relative* and *specific* heat: the former is generally applied when the determination is made as regards the volume, and the latter when it has reference to the weight of the substances.

The following table shows the specific heat of the substances mentioned, between 32° and 212° Fahr. :—

Name.	Specific heat; water = 1.	Authority.
Arsenic,	0·0814	Regnault.
Antimony,	0·0508	,,
Animal charcoal,	0·2608	,,
Charcoal strongly ignited,	0·2415	,,
,, moderately heated,	0·2964	De la Rive and Marcet.
Bismuth,	0·0308	Regnault.
Bromine,	5·1350	De la Rive and Marcet.
Cadmium,	0·0567	Regnault.
Copper,	0·0951	,,
Cobalt,	0·1069	,,
Coke—from gas retorts,	0·2023	,,
,, Anthracite, containing 3 per cent. of ash,	0·2017	,,
,, from Cannel coal, containing 4 to 5 per cent. of ash,	0·2031	,,
Diamond,	0·1469	,,
Glass,	0·1976	,,
Gold,	0·3244	,,
Graphite, natural,	0·2019	Regnault.
Graphite, artificial,	0·1970	,,
Iodine,	0.0541	,,
Iron,	0·1137	,,
Ice,	0·5130	,,
Iridium,	0·0368	,,
Lead,	0·0314	,,
Manganesium, containing carbon,	0·1414	,,
Mercury,	0·0333	,,
Molybdenum,	0·0722	,,
Nickel,	0·1086	,,
Palladium,	0·0593	,,
Platinum,	0.0324	,,
Phosphorus,	0·1887	,,
Selenium,	0·0837	,,
Sulphur,	0·2026	,,
Silver,	0·0570	,,
Tellurium,	0·0515	,,
Tin,	0·0562	,,
Tungsten,	0·0364	,,
Uranium,	0.0619	,,
Zinc,	0·0955	,,

The specific heat of bodies varies with their state of expansion, or, in other words, with any alteration in the distance of their particles from each other. Mechanical compression, sufficient to produce a permanent alteration in density, is attended by a corresponding decrease in specific heat. Regnault found the capacity for heat of a piece of soft copper to be, in two experiments, from 0·09501 to 0·09455; but after subjecting it to an atomical disarrangement by hammering, the specific heat diminished, and became 0·0936 to 0·0933. When, however, the original state of the bar was restored by annealing, an increase was experienced, and two trials gave respectively 0·09493 and 0·9479. As with solids, so also is it with liquid and aeriform bodies. When these are compressed much heat is liberated; indeed, with aeriform bodies, the heat disengaged is so abundant as to be capable of igniting tinder and other inflammable materials.

The reverse takes place when gaseous bodies are allowed to expand, by withdrawing the pressure; and in proportion as the rarefaction is greater, so also is the capacity for heat of the expansive fluid augmented.

A beautiful example of this law exists in the atmosphere. It is well known from the observations of aeronauts, and those who have ascended high mountains, that the temperature of the air decreases in proportion as the region is elevated, and that this diminution borders closely upon 1° Fahr. for every three hundred feet. Even in tropical climes some of the mountains are perpetually capped with snow, at a definite altitude, subject only to some little variation arising from the nature and distribution of the land beneath. The cause of this cold is the attenuation of the air as it extends from the earth into space, by which its capacity for heat is so greatly increased that a far more elevated temperature would be required to maintain it at the same warmth as the atmosphere near the surface of the ground. The appended table, from Daniell, gives the approximate distribution of heat by the dilatation of the atmosphere at the equator and poles, supposing the normal temperature at both these places to be respectively 80° at the former and 0° Fahr. at the latter :—

Altitude in feet.		Temperature at the Equator.		Temperature at the Poles.
0	......	80	......	0°
5000	......	64.4	......	— 18·5
1·0000	......	48·4	......	— 37·8
1·5000	......	31·4	......	— 58·8
2·0000	......	12·8	......	— 82·1
2·5000	......	— 7·6	......	— 109·1
3·0000	......	— 30·7	......	— 140·3

Taking the limit of the atmosphere to be forty-five miles high, it is probable that the most subtle and permanent gases would not only be condensed but even solidified by the degree of cold which would there act upon them, could the ordinary pressure on the surface of the globe be sustained.

Elevation of temperature also increases the capacity of bodies for caloric, and hence it requires the application of a greater heat to raise their temperature when they have combined with a large amount of caloric than in the contrary case. The appended table shows the increasing capacity of the bodies enumerated within the limits assigned:—

Name.	Capacity for heat between 32° and 212°.		Ditto between 32° and 572°.
Mercury,........	0·0330	......	0·0350
Platinum,........	·0335	......	·0355
Antimony,.......	·0507	......	·0549
Silver,..........	·0557	......	·0611
Zinc,............	·0927	......	·1015
Copper,.........	·0949	......	·1013
Iron,............	·1098	......	·1218
Glass,...........	·1770	......	·1900

Water ranks first of all bodies yet known in its increasing capacity for heat, at an increased temperature. Between 22° and 32° Fahr. the specific heat of solidified water is 0·505, assuming it to be unity in the liquid state, and if converted into steam the specific heat of the vapor increases with its state of dilatation. This property contributes in no small degree towards moderating the rapidity of the transitions from heat to cold, and *vice versa*, in the atmosphere, owing to the large quantity of heat which is absorbed by or emitted from the water of the ocean, when the temperature exceeds or falls short of the normal range.

In the determination of the specific heat of vapors, much remains to be done, to arrive at satisfactory results.

Dulong and Petit endeavored to establish the relation of the specific heat of bodies and their atomic equivalent. This relation they expressed by a general law, that the specific heats of elementary bodies vary inversely with their atomic weights; and that an atom of any one simple substance, whether small or large, has the same capacity for caloric, and requires the same quantity of this imponderable to raise its temperature through a given number of degrees, as an atom of any other element. Regnault, by observing that the product of the specific heat into the atomic weight is nearly a constant quantity, represented by 3·2°, advanced a considerable step towards establishing the existence of this general law; still, there are many exceptions which have not yet been reconciled with it.

Latent Caloric, or Heat of Fluidity.—Black asserted, many years ago, that fluidity was owing to the chemical combination of matter with a certain amount of heat, which could not be detected by the thermometer. To this he applied the term *heat of fluidity*, or *latent heat*, assuming that heat, by its chemical combination with matter, counteracted the cohesive attraction of the atoms of solids, and thus explaining the phenomenon of liquefaction, as that condition in which the cohesive and repellent forces are in exact equilibrium. This view of the subject appears to be well founded; and it is believed that the condition in which matter is found, as solid, liquid, or aeriform, entirely depends on the amount of caloric in combination with it. This has been proved with reference to most substances, and there is strong ground to believe that even the most refractory may be converted into an elastic vapor. and the most permanent of the latter class rendered solid, by the communication of heat on the one hand, and its abstraction on the other.

Solids very much vary in the phenomena which attend their conversion to fluidity: while many of them are transmuted at once to this state, others pass through various stages of softness previous to their assuming it. The following table expresses the melting or solidifying point of a few bodies:—

	Deg. Fahr
Lead melts at..............................	612
Bismuth,..................................	476
Tin,..	442
Sulphur,..................................	232
Wax,.......................................	142
Spermacceti,............................	112
Phosphorus,..............................	108
Tallow,....................................	92
Oil of Anise,............................	50
Olive oil,.................................	36
Ice,...	32
Milk,.......................................	30
Wines,....................................	20
Oil of turpentine,......................	14
Mercury,.................................	—39
Liquid ammonia,......................	—46
Ether,.....................................	—46

It must be remarked, however, with regard to the above table, that when the preceding substances in a melted state are cooled down, they do not solidify as soon as the foregoing temperatures have been attained. A further quantity of caloric must be abstracted before they assume the solid form; and, under some circumstances, this abstraction of caloric may actually be indicated by a depression of the sensible temperature extending to several degrees before any change occurs. Thus, water, which, in the form of ice, always melts exactly at 32°, may be cooled down to 8°, or even to 5°, without altering its state of aggregation. To produce this curious effect, it is necessary that no solid substance be introduced into the water. and that it be kept perfectly still; for, should the least movement of the liquid be occasioned, it would immediately begin to solidify. and the mass would rise to 32°. The sudden rise of temperature is occasioned by the evolution of the caloric which was required to liquefy the mass. and, consequently, had remained insensible to the instruments usually employed for its detection. This caloric is generally called *latent heat*; but the same term is applied to that which is contained in solid bodies, as well as to the heat of fluidity.

Much caloric is always absorbed and becomes latent by the solution of solid bodies in various menstrua, and the degree of cold which this occasions is often very great. For philosophical, and often for industrial purposes, the method followed to effect a reduction of the temperature is, to dissolve various mixtures of salts in water or spirit, and the amount of heat which is required for their solution or their reduction to the fluid state, being abstracted from these liquids, and rendered latent, is sufficient to reduce the temperature of the whole mass to a greater or less extent. The following table expresses the proportions of various substances best adapted for producing cold:—

FRIGORIFIC MIXTURES WITH SNOW.

Mixtures.	Parts by weight.	Therm. sinks—deg.	Degrees of cold.
Sea salt,	1	From any temperature to — 5	—
Snow,	2		
Sea salt,	2	to — 12	—
Chloride of ammonium,	1		
Snow,	5		
Sea salt,	10	to — 18	—
Chloride of ammonium,	5		
Nitrate of potassa,	5		
Snow,	24		
Sea salt,	5	to — 25	—
Nitrate of ammonia,	5		
Snow,	12		
Strong sulphuric acid,	1	from + 32 to — 23	55
Water,	1		
Snow,	3		
Concentrated hydrochloric acid,	5	from + 32 to — 27	59
Snow,	8		
Concentrated nitric acid,	4	from + 32 to — 30	62
Snow,	7		
Chloride of calcium,	5	from + 32 to — 40	72
Snow,	4		
Crystallized chloride of calcium,	3	from + 32 to — 50	82
Snow,	2		
Fused potassa,	4	from + 32 to — 51	83
Snow,	3		

In making the foregoing mixtures, if snow be not at hand, pounded ice may be employed with equal effect. When mixtures of salts and water are taken, the reduction is not so great; yet, when the compounds are finely powdered, and the solution rapidly effected, the cold produced is very intense:—

Mixtures.	Parts by weight.	Temp. falls—deg.	Degrees of cold.
Chloride of ammonium,	5	from + 50 to + 10	40
Nitrate of potassa,	5		
Water,	16		
Chloride of ammonium,	5	from + 50 to + 4	46
Nitrate of potassa,	5		
Sulphate of soda,	8		
Water,	16		
Nitrate of ammonia,	1	from + 50 to + 4	46
Water,	1		
Nitrate of ammonia,	1	from + 50 to — 7	57
Carbonate of soda,	1		
Water,	1		
Sulphate of soda,	3	from + 50 to — 3	53
Dilute nitric acid,	2		
Sulphate of soda,	6	from + 50 to — 10	60
Chloride of ammonium,	4		
Nitrate of potassa,	2		
Dilute nitrous acid,	4		
Sulphate of soda,	6	from + 50 to — 14	64
Nitrate of ammonia,	5		
Dilute nitric acid,	4		
Phosphate of soda,	9	from + 50 to — 12	62
Dilute nitrous acid,	4		
Phosphate of soda,	9	from + 50 to — 21	71
Nitrate of ammonia,	6		
Dilute nitric acid,	4		
Sulphate of soda,	8	from + 50 to 0	50
Hydrochloric acid,	5		
Sulphate of soda,	5	from + 50 to + 3	47
Dilute sulphuric acid,	4		

The acids should be prepared by adding two parts by weight of the fuming nitric acid to one of water, and allowing the mixture to cool. When working with sulphuric acid, equal weights of strong acid and water are taken, and used after cooling.

A still more intense degree of cold may be attained by the rapid evaporation of liquids, such as bisulphide of carbon, ether, protoxide of nitrogen, and solid carbonic acid gas. By employing a bath of carbonic acid and ether *in vacuo*, FARADAY reduced the temperature

166° Fahr. below zero; and NATTERER, by means of bisulphide of carbon and protoxide of nitrogen, brought the thermometer to — 220°. The cause which operates in the case of the solution of solids in snow and water, or acids, is the same that induces the frigorific effect by rapid evaporation; but as the caloric which is rendered insensible or latent in the conversion of a liquid body to a gaseous state, is much greater than is necessary to convert a solid to the liquid form, hence it results that the depression of temperature produced by a rapid evaporation can be carried further.

Latent heat, the amount of which differs in different bodies, serves very important offices in the economy of nature, as well as in the chemical manufactures. When the temperature of the atmosphere in winter rises to 32°, masses of ice and vast accumulations of snow would suddenly liquefy, producing destructive inundations, were it not that in melting they must further absorb the heat of fluidity, which becomes latent, and thus the change is retarded and rendered gradual. In the manufactures, the importance of latent heat is illustrated by the employment of steam as the heating agent in numerous processes of distillation, evaporation, and carbonization; but the manner in which it acts in these cases will be better understood after some further explanation of the effect of heat upon liquids.

It has been shown that the change from the solid to the liquid form is the result of the combination of a certain amount of caloric with the substance, and that the heat so united becomes insensible to the thermometer, however delicate its construction. Instances of the absorption and disappearance of heat have been given in the melting of ice, metals, and other substances, capable of passing into the liquid state. In the fusion of metals, the temperature of the bath does not increase a fraction of a degree above the melting point, till the whole has undergone liquefaction, notwithstanding that heat has been pouring into the mass without intermission. The reason of this is, that as long as any of the metal remains solid, it abstracts all the excess with which the liquid may be charged, and combines with it to form more fluid. After the latter stage has been attained, if the temperature be still increased, the bath will continue to indicate a rising temperature till it acquires that degree at which the repulsive force of the caloric will have so far overcome the cohesion of the particles, as to expand them to such an extent that their gravity will be less than that of the air, bulk for bulk. The liquid will then be gradually transformed into vapor, and will manifest the phenomenon of ebullition, which is simply the commotion produced by the evolution of bubbles of the substance itself converted to the gaseous state, and which are generated by its union with the caloric supplied to the liquid. Whatever additional heat be now applied, the boiling fluid will continue to indicate the same temperature as long as any of it remains; and during the process, the vapor which escapes possesses *apparently* only the same amount of caloric as the liquid from which it is produced, but *actually* a greater amount in the shape of the additional *latent heat* by which it is converted into vapor.

These changes are more familiarly known as happening with water than with metals, for although the latter are frequently fused, they are seldom converted into vapor. During the melting of ice by the application of heat, the ice, or mixture of ice and water, remains at 32° till the whole is melted; it is evident, however, that the water at 32° must now contain more heat than when, in the state of ice it indicated the same temperature. If heat continue to be applied, the water gradually acquires a temperature of 212°, at which point, provided the atmosphere be at the usual standard barometric pressure, and the liquid be contained in an open iron or copper vessel, it remains stationary. It is now rapidly converted into vapor, but both the liquid and vapor are still at the temperature of 212° Fahr. A little consideration will show that the heat which continues to flow into the liquid, is expended in converting it into steam; for as no indication of an increase is manifest, it must be evident that the surplus is rendered insensible in the process of converting the water into vapor. The quantity of heat necessary to effect this is much larger than is required to reduce the body from the solid to the liquid state. To estimate the amount of caloric expended and rendered insensible or latent in both cases, let a pound of water at 212° be mixed with the same weight of water at 32°, and it will be found that the mixture will indicate a medium between these points—that is to say, the pound of water at 212° will lose 90°, and the pound of water at 32° will gain 90°; so that the mixture will indicate 122°. But now let a pound of water at 212° be mixed with a pound of snow or ice at 32°, and the mixture will indicate only 51° Fahr., showing that the water has lost 161°, while the snow or ice has gained *apparently* only 19°. It is evident that the difference between these figures, or 142°, must have been absorbed or become latent in converting the snow or ice into water.

Applying the same test to steam or vapor of water at 212°, it will be found that one pound of water, which has been converted into steam, is sufficient to reduce six pounds and a quarter of snow or ice to the liquid state, and to raise it to 51°, from which it may be deduced that steam contains 967° of latent or insensible heat. LAVOISIER estimates the amount, in round numbers, at 1000°.

EBULLITION AND EVAPORATION.—During the ebullition of water in common metallic vessels at the ordinary pressure of the atmosphere, no amount of heat applied can elevate its temperature beyond 212°, provided the steam passes off freely; a fact which is well deserving of consideration in domestic economy. Many causes, however, tend to vary the boiling point of water and of liquids in general. If it be contained in smooth glass vessels, ebullition takes place at two or three degrees above the usual standard; hence, if a coil of wire be introduced into water contained in a smooth glass vessel, and near the point of ebullition, this process will commence immediately. All angular bodies, and more especially metals, introduced among the liquid, cause the boiling to take place even in glass vessels at 212°. The adhesion of the liquid to the sides of such vessels seems to be the cause of impeding the boiling, and sometimes of making it to pass into vapor suddenly; hence in distilling in the laboratory the custom of introducing bits of platinum wire into the retort to facilitate the conversion of the liquid into vapor; without this precaution there is often danger of the retort being broken, or of the liquid operated upon being thrown over into the receiver. At each evolution of vapor that is formed during ebullition under these circumstances, the temperature falls to 212°; but when it has escaped, the contents of the vessel remain quiet till the temperature rises as before. Many substances, such as shell-lac, when applied to the interior of the vessel, prevent ebullition taking place at the usual degree; but the experiments of Dormy have proved that atmospheric air mixed with liquids influences their boiling point more than anything else, except pressure. He showed that the air which is dissolved in water acquires an increased elasticity, and forms minute bubbles in the interior of the fluid into which the steam dilates and rises to the surface. By long-continued boiling the air is nearly expelled; and in the course of some experiments it was found that the temperature could be raised to 360° in an open vessel without the phenomenon of ebullition taking place; finally, however, the disengagement of vapor was so sudden that it caused a loud explosive report, and shattered the vessel in fragments.

From what has been said, it is evident that the boiling point of liquids is not fixed, but is dependent upon various causes. The greatest effect is produced by the varying pressure of the atmosphere, which on an average is about fifteen pounds for every square inch of surface at the level of the sea; but the weight of the air varies at different heights, and according as it happens to be surcharged with watery vapor or not; consequently, at different elevations the boiling point will be different, and even at the same level the pressure or density varies so much as to cause a difference of four degrees or more of Fahrenheit's scale. It is absolutely necessary, therefore, to observe the pressure of the atmosphere when fixing the boiling point of liquids on the thermometer, and to make the necessary corrections. This is done by noting the height at which the mercury in the barometer stands at the time, and making the requisite allowance for any difference between that and the normal height of 29·92 inches, as shown by the following table, which embraces the extreme indications of the barometer at common levels, with the boiling points of water corresponding to these and the intermediate indications:—

Barometer Indication. Inches.	Water boils. Deg Fahr.
27·74	208
28·29	209
28·84	210
29·41	211
29·92	212
30·6	213

It thus appears, that under a diminished pressure water boils at a lower temperature, and the same happens with other liquids. Saussure found that, on the top of Mont Blanc, water boiled at 184° Fahr. In deep mines, on the contrary, it requires a much higher temperature than 212° to bring it to a state of ebullition. On this circumstance has been based the construction of an instrument for determining the heights of mountains by the boiling point of water or other liquids.

When the pressure is removed by artificial means, as by creating a vacuum, the boiling point of water may be lowered about 145° under the usual temperature at which ebullition takes place. This has been turned to advantage in several manufacturing processes, where an exposure to the temperature of boiling water, under ordinary circumstances, for a length of time, would be prejudicial and sometimes destructive to the substances under treatment. The pharmaceutist and sugar-refiner are especially benefited by the application of this important fact in their respective processes. By operating under a low pressure, produced by creating a partial vacuum, the former can readily inspissate his vegetal juices to any desired extent without injury; whereas, if the same were attempted in an open vessel under the common atmospheric pressure, most of the active principle would be destroyed. In like manner, if the saccharine liquid of the sugar boiler were to be concentrated to the same degree to which it is usually carried in an open pan or boiler, nearly the whole of the crystallizable sugar would, by an allotropic molecular arrangement, pass to an uncrystallizable sirup. By an increased pressure the converse of this happens, and water may be made to attain a temperature of 300°, 400°, or upwards, before ebullition. An instrument known as Papin's digester, which is simply a strong metallic vessel with a safety valve, is constructed on this principle, and is used to macerate bones and other substances in liquids raised to a higher temperature than that of boiling water.

Solid bodies dissolved in water or other liquids produce, to a certain extent, the same effect as high pressure; generally, the elevation of the boiling point varies according to the nature of the substance in solution, but it uniformly increases with the same body till the liquid is saturated. Tables founded upon this law have been drawn up, for the purpose of estimating the amount of saline matter in a liquid from its boiling point.

Ebullition consists mainly in the conversion of the liquid into vapor, and so far is synonymous with evaporation; which differs from it, however, inasmuch as the latter takes place at all temperatures—whereas a certain range of temperature is required, under any circumstances, before the former phenomenon is observed. This may be proved by allowing a shallow vessel containing water to remain exposed for some time; upon examination it will be found that a portion will have disappeared—or, in other words, it will have evaporated to the extent of the loss. Most fluids are susceptible of this change, but those which boil at a low temperature are more volatile than others: thus alcohol is evaporated much quicker than water, and for the same reason ether is converted into vapor much more readily than even alcohol.

Evaporation is affected by the temperature and hygrometric state of the air, and the extent of surface exposed. It is evident that the latter must influence the rate of conversion into vapor, because this alteration can only take place at the surface: hence the amount of evaporation will be, *cæteris paribus*, in proportion to the superficies which the fluid presents. But when the air is surcharged with moisture, the change into vapor will be slow, even although the temperature be elevated, whereas, if it be dry, the fluid will disappear much quicker. In still air the evaporation is much slower than when a breeze or current of air is passing over the liquid; because, in the former case, the stratum of air immediately over the surface of the fluid becomes saturated and unable to take up any more moisture, whereas, when a current is established, a fresh and dry stratum is constantly presented to the liquid, and passes away loaded with vapour.

Evaporation, like ebullition, is greatly promoted by the removal of pressure; thus, by placing a cup containing ether or any other volatile fluid under the receiver of the air-pump and exhausting it, the fluid rapidly disappears, and an atmosphere of vapor is formed.

In all cases, however, where it is expedient that liquids should be quickly vaporized, heat is resorted to as the best and most ready agent. Heat, indeed, is the cause of evaporation at whatever degree or under whatever circumstances it takes place, just as it has been shown to be the cause of liquidity. Hence arises the important question, What is the least quantity of caloric required to effect the evaporation of a given quantity of liquid?—a question which bears on the economy of fuel in the generation of steam, and in many other manufacturing processes. Mr. Sharpe, of Manchester, arrived at the conclusion, that as the latent heat of vapor is increased with its degree of rarefaction, and as subtler vapor is obtained at low than at more elevated temperatures, there is no economy of caloric, and therefore no saving of fuel by evaporating or distilling liquids *in vacuo*. Watt further showed that the same weight of steam, whatever density it may possess, contains the same quantity of heat, its insensible or latent caloric being increased in proportion as its sensible is absorbed. Thus he found that a given weight of steam at 212°, and consequently possessing 180° of sensible heat above the freezing point, gave off 950° more when condensed by injecting upon it water at 32°, making, with the sensible heat, a total of 1130° above the point of freezing. Again, the same weight of steam at 250°, and therefore possessing 218° of sensible heat, gave out, on being liquefied at the same temperature, only 912° Fahr., which, with the sensible heat, amounted exactly to 1130° also. This he assumed, therefore, as the amount of caloric necessary to convert water at 32° into steam, either of a high or low tension; and hence, on this assumption, to ascertain the amount of latent or insensible heat in steam, at any temperature, all that is necessary is to deduct the sensible heat from 1130°, and the difference is the latent caloric.

These experiments appear to lead to the inference that, in the evaporation of liquids, generation of steam, distillation, *et cetera*, no material economy is gained by conducting these processes at low rather than at high temperatures; but the later and more carefully conducted researches of Regnault have shown that this assumption is not strictly correct, and although the difference does not lead to serious errors in practice, yet in reality the sum of the latent and sensible heat increases for each degree of Fahrenheit, by a constant quantity equal to 0·305°. This is illustrated in the annexed table, in which it is assumed that steam possesses no sensible heat below Fahrenheit's zero:—

LATENT AND SENSIBLE HEAT OF STEAM AT DIFFERENT TEMPERATURES:—

Pressure in atmospheres.	Temperature.	Latent heat.	Sum of latent and sensible heat.
0·014	0°	1114°	1114
0·180	32	1091·7	1123·7
1·000	212	[illegible]	1178·[illegible]
8·000	339	877·3	1216·8

The increase here shown offers, however, but a small inducement to perform the processes already alluded to at low temperatures—so far as saving of fuel is concerned; while the increased amount of sensible heat which may be utilized advantageously when the steam is generated under pressure, renders it expedient that the latter mode of generating it should be resorted to. This is the case especially when steam is employed as a source of heat in the carbonization of ligneous matters, in the distillation of liquids, and, occasionally, in the concentration of saline and extractive solutions. The large amount of caloric which steam possesses renders it peculiarly adapted to such purposes; and hence, in all those manufactures where the products are of a salifiable or an extractive nature, steam is now generally employed to concentrate the liquors. In the culinary art, also, it is found to be much more eligible as a source of heat than the common method of exposing the apparatus directly to the action of fire. It is especially adapted for drying manufactured goods and for purposes of ventilation; in the one case, it is conveyed through cylinders over which the goods are conducted, and in the other through iron pipes, so disposed that the heat shall be given off in the most effectual way. In the latter case, experience has shown that the boiler should have one cubic foot capacity for every two thousand cubic feet of air to be heated to a temperature of 70° or 80° Fahr., and that the conducting pipe must present a superficies of one square foot for every two hundred cubic feet of space to be heated.

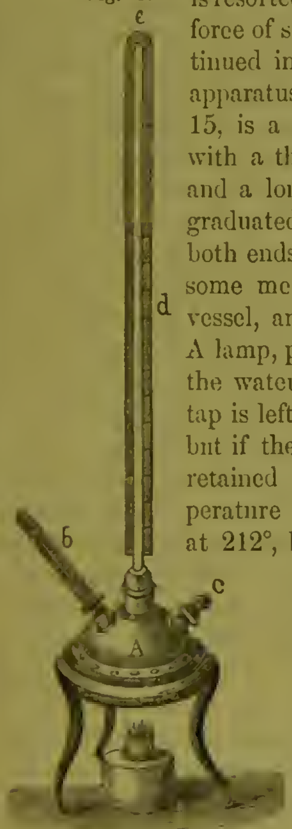
Elastic Force of Steam.—When different liquids are heated to their boiling points, they produce very unequal quantities of vapor. Water yields it in larger volume than any other known liquid. The following table shows the volume of vapor produced by a cubic inch of each of the liquids enumerated at their respective boiling points:—

Cubic inch.			Cubic inches.	
1	of water	expands to	1696	at the boiling point.
1	of alcohol	"	528	" " "
1	of ether	"	298	" " "
1	of turpentine	"	193	" " "

The great value of machinery at the present day in developing the resources of nations, and in fostering and extending commerce and internal intercourse, turns upon the expansive property of water under the influence of heat. This, as already stated, is such as to make it the most efficient motive power; and although it requires a higher temperature, and consequently a greater consumption of fuel, to generate vapor from it than many other liquids, yet its superior elasticity in the shape of steam is such as to render it preferable to any of them, even supposing they could be had as cheaply. When the vapor of water is heated alone, the rate of expansion is the same as that of air or any other elastic gaseous mixture when subjected to an equal temperature, and it may be confined in red-hot vessels without a great amount of elastic force being acquired. It is otherwise, however, if some water be contained in the vessel or cylinder, for then the generation of fresh vapor causes an addition of elastic force to that already exerted, so that in time the pressure on the walls of the vessel becomes irresistible.

PAPIN'S digester, already mentioned, or an apparatus constructed on similar principles, is resorted to for determining the elastic force of steam when subjected to a continued increase of temperature. This apparatus, which is represented in Fig. 15, is a globular vessel, A, furnished with a thermometer, *b*, a stopcock, *c*, and a long glass tube, *d*, affixed to a graduated scale, *e;* the tube is open at both ends—the lower one dipping into some mercury in the bottom of the vessel, and on which the water floats. A lamp, placed under the globe, causes the water to boil, and so long as the tap is left open, this happens at 212°; but if the steam which is produced be retained by closing the tap, the temperature no longer remains stationary at 212°, but rises progressively as the steam is accumulated; and the mercury, which before marked only a height equivalent to thirty inches in the tube, now ascends till it reaches twice or thrice that elevation, according as the elastic force of the steam is increased.

Fig. 15.



DULONG and ARAGO have made some researches upon this subject, which are valuable, inasmuch as they throw considerable light upon the mechanical effect of steam. The results are, therefore, appended in the following table, from which it may be seen, that as the temperature rises, a given increment of heat produces a greater effect in augmenting the elastic force than at a lower temperature. If the atmospheric pressure, or the elasticity of steam at 212° Fahr., be taken as unity, the elastic force of steam at 240° Fahr. will be about one and a half, and at 250° Fahr. will be equal to two atmospheres. Thus an increase in the quantity of heat indicated by 38° Fahr. doubles the elastic force, and it also appears from the table that a further increase of 25° trebles the elastic force, and a further increase of only 18° quadruples it. Thus the elastic force evidently increases much more rapidly than the temperature. This circumstance has led to the introduction of high-pressure boilers as affording an increased motive power, with a less consumption of fuel, than when low-pressure boilers are used. The former have been found so advantageous, that, in mining and manufacturing districts, as well as for locomotives and steam vessels, high-pressure steam is now in general use :—

ELASTICITY OF STEAM AT HIGH TEMPERATURES.

Elasticity of steam, taking atmospheric pressure as 1.	Temperature Fahr.	Elasticity of steam, taking atmospheric air as 1.	Temperature Fahr.
1	212°·0	13	380°·66
1½	239·96	14	386·94
2	250·52	15	392·86
2½	263·84	16	398·48
3	275·18	17	403·82
3½	285·08	18	408·92
4	293·72	19	413·78
4½	300·28	20	418·46
5	307·5	21	422·96
5½	314·24	22	427·28
6	320·36	23	431·42
6½	326·26	24	435·56
7	331·70	25	439·34
7½	336·86	30	457·16
8	341·78	35	472·73
9	350·78	40	486·59
10	358·88	45	491·14
11	366·85	50	510·60
12	374·00		

COMBUSTION.—Allusion has already been made in the preceding pages to various sources of heat; but those which will fall to be considered in connection with the subject of this article, are certain material substances which, in the act of undergoing chemical changes, yield both heat and light. This process is termed combustion. At one period, and among the disciples of LAVOISIER in particular, oxidation and combustion were considered synonymous. It is true, that in most cases of combustion, as in that of a common fire, the effect is produced by the oxidation of the materials; but cases of combustion occur when no oxygen is present. Antimony, for example, burns when heated in an atmosphere of chlorine; copper, or iron, when heated with sulphur; potassium, with cyanogen, *et cætera*. These instances demonstrate the fact that oxygen is not essential to combustion, although it is eminently capable of supporting it; and being so extensively disseminated in the atmosphere, it acts as the almost universal agent in this phenomenon.

Though the term *combustion* is generally limited to cases of chemical combination accompanied with heat and light, yet it is sometimes extended to express the union of bodies with oxygen effected at a low temperature. Iron, for example, when exposed to moist air, undergoes a change in oxidizing, whereby its metallic characteristics disappear; the constituents of the blood are modified by a similar chemical process, but in neither case is light produced; and if heat is generated in the former, it is quite inappreciable even by delicate instruments. In both cases, however, the effect produced is sometimes characterized as a process of *slow combustion.*

In cases of vivid, as distinguished from slow combustion, the heat and light seem to be evolved from the solid, liquid, or gaseous bodies which burn, and hence they are termed *combustibles*, while the gaseous atmosphere in which they are involved, such as oxygen or chlorine, is termed the *supporter of combustion*. It is evident, however, that this distinction is radically faulty, inasmuch as the phenomena of light and heat may be regarded as proceeding either from the one or the other. The combustible, usually so called, may be represented as supporting the combustion of the atmosphere in which it is enveloped, and the latter, regarded in this view, becomes the real combustible. In strictly philosophical language, the combustion proceeds from the combination, which can only take place at the point of contact; and therefore it is quite impossible to say to which of the bodies so combining is due the evolution of heat and light, or, in other words, which is the combustible and which the supporter of combustion.

Much difference of opinion exists as to the manner in which heat is produced, and the question is far from being solved at the present time. At one period it was thought that heat was a material constituent of the substance, which might be separated from it or combined with it like other substances. On this hypothesis all the gaseous bodies were regarded as compounds of the actual matter with the substance of heat and light, or *phlogiston*, as it was called; and when any one of these, such as oxygen, was made to unite with another body, and heat and light accompanied the combination, these phenomena were attributed to the evolution of phlogiston. Moreover, to account for the fact that some bodies, as metals, gained in weight by combustion, the phlogiston was supposed to be possessed of a principle of levity. LAVOISIER explained the evolution of caloric when certain bodies entered into combination, on the supposition that the specific heat of the substances before combustion was greater than that of the bodies produced, and that the difference was what was radiated or otherwise evolved from the burning body. Experiment, however, has shown that this theory is untenable, for in the case of the combustion of carbon, which is the commonest instance, the carbonic acid gas produced has a greater instead of a less specific heat than oxygen; and hence, in a case where caloric is actually given off, the result is found to be the very reverse of that which is implied in this explanation. More recently, THOMSON accounted for the effect on the assumption that every atom or molecule of simple bodies contains an equal amount of heat, and that, when a number of them combine, the caloric from one or more is expelled. But all these theories may be ranked as mere ingenious speculations. In the present state of knowledge, all that can be affirmed with certainty is the general principle, that heat is developed by chemical action.

Relative Value of different Combustibles.—The amount of caloric produced in the combustion of different bodies is variable, and the determination of the quantity so produced becomes a matter of the highest importance, as upon this depends the selection of particular substances for the production of heat economically. The course pursued in researches with this object in view is to burn a certain weight of the combustible, admitting for this purpose only the smallest possible quantity of oxygen or air, and so to conduct the heat through water that it shall be entirely absorbed by it. From the quantity of liquid raised through a certain range of temperature, the value of the combustible under experiment is estimated.

Proceeding upon this plan, and comparing a number of results, WELTER concluded that the heat disengaged depended upon the quantity of oxygen taken up, and that the amount developed by equal weights of oxygen, when made to unite chemically with other bodies, how different soever they might be, was always the same. In this opinion he was supported by the researches of other chemists. DESPRETZ, by uniting one pound of oxygen with any of the following substances, found that the water raised from 32° to 212° Fahr. was, with

Hydrogen,....................	29·5	pounds.
Charcoal,....................	29	"
Alcohol,....................	28	"
Ether,....................	28·5	"

Although the law laid down by WELTER appears to be confirmed by these results, yet there are several facts with which it does not accord. When iron is oxidized and the generated caloric is collected in water, the quantity heated by it from 32° to 212° is fifty-three pounds, or nearly double the weight which the same volume of the gas consumed with the substances above enumerated raises to the boiling point. Zinc, tin, and many other metals, similarly treated, produce effects which differ in like manner from the results tabulated by DESPRETZ. Even the same quantity of oxygen produces unequal effects with the same body, when it is capable of combining with it in various proportions. Thus, when phosphorus is burned slowly, the amount of heat which it evolves in combining with one pound of oxygen is capable of heating only twenty-eight pounds of water to the boiling point; but when the combustion is conducted rapidly, so as to produce phosphoric instead of phosphorous acid, twice as much caloric is disengaged. Again, if charcoal be consumed with a limited supply of oxygen, so as to form carbonic oxide gas, and a quantity of this gas equivalent to one pound of carbon be ignited, it will be found that as much heat will be given off as will raise sixty-two pounds of water to the boiling point; whereas, if the carbon be ignited with its full complement of oxygen in the first instance, the heat obtained will be to the foregoing as 76·62, whilst the proportion of oxygen combined is as 2 to 1. From all these cases it appears that the quantity of heat developed by the combustion of a substance depends greatly upon the nature of the body itself. It cannot be denied, however, that the volume of oxygen which combines with the substance affords in most cases a pretty near approximation to the amount of heat developed in combustion; and hence the method in ordinary use for determining the heating power of combustibles by the reduction of litharge, which will be noticed further on.

But there are other considerations which must likewise be taken into account in estimating the relative value of different kinds of fuel. Very many substances which are capable of giving out considerable quantities of heat cannot be used for that purpose: first, because their cost would exceed the limits of economy; and, secondly, because a too elevated temperature would be required to induce combustion. Such is the case with a great number of metals, which, under certain circumstances, are capable of evolving intense heat and light during their union with oxygen. On the other hand, there are many substances which may be made to undergo the process with comparative facility, but cannot be usefully turned to account, because they evolve obnoxious products, such as arsenical or sulphurous gases; others again require, for their combustion, a too complex apparatus, and too constant surveillance, to admit of their useful application.

The substances which combine the greatest facility of combustion with the production of a large amount of caloric, are carbon and hydrogen; and there is never wanting in the atmosphere a third, with which to combine—namely, oxygen. The product of the union of the first of these substances with oxygen, that is to say, of its combustion, is carbonic acid gas, a compound poisonous indeed when breathed alone, but destitute of odor, and colorless. Where common means of ventilation exist, there is no danger to be apprehended from this gas, and it cannot accumulate in the air to such an extent as to act injuriously; for on descending again to the earth it becomes the food of vegetals, by which it is analysed into its elements, and these are again rendered available for performing the same service. The combustion of hydrogen, or, in other words, its union with oxygen, yields only water, which, like the carbonic acid, is subjected to other transformations in nature's laboratory, whereby its elements are again separated, and therefore perform the same office over and over again without any diminution or loss of effect. It is impossible not to admire the wisdom and benevolence of that arrangement whereby these three elements are produced in quantities so enormous, they being far the most necessary materials towards the support of animal life. Regarded as sources of fuel, they are all conveniently stored in wood and other vegetals, of which a continual reproduction insures an abundant supply.

ARTICLES OF FUEL.—The substances usually employed as fuel are *wood*, *peat*, and *coal*, either in their natural state, or modified by peculiar treatment. The abundance of these in a country must always constitute a principal source of its wealth, more especially now that steam has become the moving power of manufacturing industry, as well as the great agent in locomotion. It is evident, therefore, that none of the productions of nature should be more carefully husbanded than those which constitute fuel. Every attempt also to improve the quality of inferior materials, so as to increase their efficiency as heat-producers, ought to be liberally encouraged; and some efforts in this direction have lately been made with much success.

Wood, peat, and coal, though so different in physical appearance, are nevertheless very closely allied in composition, all the three being chiefly composed of ligneous fibre, a compound of three simple elements—carbon, hydrogen, and oxygen. Physical effects have induced certain changes in some kinds of peat and coal, which cause them to differ considerably in their properties from woody fibre; but, by observing the action which analogous artificial agencies exert upon the latter, a remarkable coincidence is observed, and sufficient data are found for inferring that woody fibre is the basis of these substances, although they have passed in the course of time through various chemical transformations. The extent of the changes thus induced may be, to some degree, inferred from the phenomenon of combustion. Woody fibre, when deprived of extraneous moisture, readily bursts into a flame upon being ignited, whilst many kinds of coal do not. The difference is caused, firstly, by the states of density of these substances; and, secondly, by the absence of hydrogen and oxygen in the coal. Porosity and the presence of hydrogen in combustible bodies facilitates rapid combustion. When hydrogen is a constituent, it is liberated at a temperature below redness, in union with a portion of the carbon, from all the pores of the substance, and forms around the latter an inflammable atmosphere, which bursts into flame at slightly increased heats; the evolution of this matter leaves the remainder open to the passage of oxygen, which effects its rapid combustion.

The production of flame is always connected in a remarkable manner with the presence of hydrogen, but in some cases the phenomenon may be observed where this element is absent; thus, when pure charcoal or anthracite coal is burned in a limited supply of oxygen or air, instead of carbonic acid being generated, an inflammable gaseous body results, which re-ignites when a further quantity of air or oxygen is admitted, and produces flame. A characteristic difference is, however, observed between the sheet of light which is given out by a combustible containing hydrogen, and that from carbonic oxide; the former is luminously brilliant, as is seen in gas, whilst the latter is dull, bluish, and attenuated. The property of producing flame determines particular uses for many species of fuel, such, for instance, as choosing cannel for the manufacture of gas, and of inflammable varieties for the heating of reverberatory furnaces where the materials are at a distance from the fire. A selection of this class, for purposes where local heat is wanted, such as in the reduction of ores and in the manufacture of iron, would be injudicious, and, consequently, the less inflammable, or such as have been divested of hydrogen, are in these cases resorted to.

WOOD—*Bois*, French; *Holz*, German.—This is the name given to the hard porous tissue of plants, through which sometimes the liquid sap is raised by capillary attraction, though more generally the latter traverses between the bark and these tissues. The wood of large trees is called timber, and is generally applied to architectural and domestic uses. It is only, however, in connection with its use as a combustible or source of heat that it will be discussed in the following pages.

Chemically considered, wood is composed of several substances, both of an organic and an inorganic nature, but of these the former alone are productive of heat. Woody fibre, or the tissue already noticed, constitutes the basis of the mass, whilst the sap, water, and other matters peculiar to the species of wood, make up the remainder. All kinds contain water and woody fibre, so that the sap and extractive matters are the substances which determine the particular species of this organic production. Thus, many woods, especially the coniferous, are resinous; others, such as beech and birch, contain extractive matters; and many others, definite chemical compounds, such as tannin, and the like. All these may be removed by the successive action of water, alkalies, and alcohol; and although the principles in the several varieties are different, yet they all afford a close approximation in the quantity of carbon, hydrogen, and oxygen which the wood contains.

Various concurring circumstances tend to enhance the value of wood as a fuel, such as freedom from water, density, *et cetera*, and it is upon these qualifications that its marketable value turns.

Amount of Moisture in Woods.—A remarkable variation is observed at stated seasons, in the quantity of soluble matter—sap—which is present in all kinds of woods: thus, in spring, when the tree is in active growth, the amount of water, *et cetera*, is much greater than at the close of autumn, or the middle of winter, when it is in a kind of normal state. The practical benefit of this knowledge is, that trees, whether intended for fuel or timber, are, or should be, felled in the latter seasons; although, when they are cultivated for the principle of the sap, such as tannin, quinin, *et cetera*, it is more advantageous to cut them when the flow is at its full.

SCHUBLER found in woods felled at the end of January and the beginning of April, an extensive difference in the amount of contained moisture, as may be seen from the appended results:—

Species.	Felling time.	Water.	Felling time.	Water.
Ash	End of January,	28·8	Beginning of April,	35·6
Sycamore	"	33·6	"	40·3
Horse Chestnut,	"	40·2	"	47·1
White Fir,	"	52·7	"	61·0

Sap is unequally disseminated in various parts of trees: in the trunk, it is accumulated more in the exterior than in the core, and still more in the branches than even in the outer portions of the trunk. Wood, cut at the proper time, retains from one-fifth to one-half its weight of moisture, part of which is lost by exposure to the air.

SCHUBLER and NEUFFER'S experiments give the following as the per centage of water in the several species enumerated:—

	Water Centesimally.
Hornbeam—*Carpinus betulus*,	18·6
Willow—*Salix caprea*,	26·0
Sycamore—*Acer pseudo-platanus*,	27·0
Mountain Ash—*Sorbus aucuparia*,	28·3
Ash—*Frasinus excelsior*,	28·7
Birch—*Betula alba*,	30·8
Wild Service Tree—*Cratægus tormin*,	32·3
Oak—*Quercus robur*,	34·7
Pedicle Oak—*Quercus pedunculata*,	35·4
White Fir—*Pinus abies dur*.,	37·1
Horse Chestnut—*Æsculus hippocast*,	38·2
Pine—*Pinus Sylvestris L*.,	39·7
Red Beech—*Fagus sylvatica*,	39·7
Alder—*Betula alnus*,	41·6
Aspen—*Populus tremula*,	43·7
Elm—*Ulmus campestris*,	44·5
Red Fir—*Pinus picca dur*.,	45·2
Lime Tree—*Tilia europæa*,	47·1
Italian Poplar—*Populus italica*,	48·2
Larch—*Pinus larix*,	48·6
White Poplar—*Populus alba*,	50·6
Black Poplar—*Populus nigra*,	51·8

From the numerous experiments performed by CHEVANDIER, with the view of determining the loss sustained by woods of different ages, and by the several parts of the same tree when exposed to the air during stated periods, it may be inferred, that so far as the abandoning of moisture to air was observed, the soil and locality where the trees grew did not affect the results. The samples submitted to examination were exposed in a shed, which protected them from rain as well as from the sun's rays, and the moisture was determined at the several stages, by drying a portion of the sample in the form of sawdust, at a temperature of 284° Fahr. *in vacuo*, till it ceased to lose weight. By this procedure, it was found that the maximum loss by exposure was sustained, in the greater number of cases, after a period of a year and a half, although many specimens required two years to reduce their hygrometric contents in the same degree. It appeared, likewise, that the resinous varieties part with their water more freely than the non-resinous; they, on the other hand, absorb water with greater avidity when exposed to moist air than the latter. The softer non-resinous woods always contain more water when cut down than the harder kinds, but they part with it more freely, and can be desiccated to a greater extent than the latter.

The following is a synopsis of the results of researches on this subject, transcribed from the valuable treatise of RICHARDSON and RONALDS:—

1. MEAN TEMPERATURE OF HYGROMETRIC WATER CONTAINED IN RESINOUS WOODS:—

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling	29
Brush-wood "	32
Young Branch-wood "	38
Trunk-wood in the driest state,	15
Brush-wood "	15
Young Branch-wood "	15

2. MEAN QUANTITY OF HYGROMETRIC WATER CONTAINED IN THE NON-RESINOUS WOODS.

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling,	26
Brush-wood "	34
Young Branch-wood "	36
Trunk-wood in the driest state,	17
Brush-wood "	20
Young Branch-wood "	19

These results may be viewed as the minima, because the single specimens would be more thoroughly exposed than if made up into stacks; and it may, therefore, be inferred, that after exposure under favorable circumstances during a year, the wood still retains about one-third of its weight of moisture, for the expulsion of which a prolonged heat is required. In ordinary air-dried firewood, this amount of water, together with that which results from the oxygen and hydrogen contained in it, is vaporized at the expense of the carbon, and the consequence is, that much of its value as fuel is lost when used in this state. In such applications where a brisk temperature is indispensable, the material is never used after merely air-drying, but is exposed to such a degree of heat as will drive off this moisture, so that, when ignited, the entire weight may be serviceable for the generation of heat. To do this thoroughly requires great care, because, unless the heat is sufficiently elevated, the moisture will not be removed, and when it is capable of exerting a thorough hydrotic effect, the constituents of the wood will be apt to arrange themselves so as to form gaseous matters, which are dispelled into the air, and thus a loss to some extent is sustained. Even when so treated that it does not retain any moisture, it becomes so hygrometric, that, upon exposure, it readily assimilates from eight to ten or more per cent. of water even in dry weather.

Density of different Woods.—When felled, nearly all kinds of wood are lighter than water, although the solid portions are possessed of a much higher density than this liquid; a few are, however, heavier than water, but these are the harder kinds, in which the cellulose is so closely packed together, that very little room is left for the retention of air. In their ordinary state, the woody matter, water, and air, concur to confer the gravity, but as the latter bodies considerably vary in amount, much difficulty is attendant upon the proper determination of the density. It will be understood, however, that so far as the moisture is concerned, it acts a neutral part, and the greater gravity of the solid portions is reduced by the volume of air in the pores. Again, as the hydrogen and oxygen of the woody fibre, as will be seen further on, are present in the ratio of their existence in water, or nearly so, and so solidified that they make up about the same volume as when actually combined in the form of water, it is evident that the greater weight of any specimen must be owing to the larger amount of carbon in the same bulk, excepting the slight difference which is due to the mineral constituents. The following table exhibits the density of several kinds of wood, according to Brisson, water being taken as unity :—

Variety of Wood.	Density	Variety of Wood	Density.
Pomegranate, ...	1·35	Maple, ...	0·75
Ebony, ...	1·33	Cherry-tree, ...	0·75
Dutch Boxwood, ...	1·32	Orange-tree, ...	0·70
Heart of Oak (sixty years old), ...	1·17	Elm —the trunk, ...	0·67
Medlar, ...	0·94	French Walnut, ...	0·67
Olive, ...	0·92	Pear-tree, ...	0·66
French Boxwood, ...	0·91	Spanish Cypress, ...	0·64
Spanish Mulberry, ...	0·89	Lime-tree, ...	0·60
Beech, ...	0·85	Hazel, ...	0·60
Ash—the trunk, ...	0·84	Willow, ...	0·58
Spanish Yew, ...	0·80	Male Fir, ...	0·55
Apple-tree, ...	0·79	Spanish White Poplar,	0·52
Dutch Yew, ...	0·78	Female Fir, ...	0·49
Plum-tree, ...	0·78	Poplar.	0·38
		Cork, ...	0·24

When common woods that are thoroughly dried and rasped so as to destroy their porosity are weighed with proper precautions, their density is found to be higher than that of water; and Rumford remarks that the solid portion of all the species of wood, wherever and under whatever circumstances grown, exhibits a remarkable identity in point of gravity, which he estimates at 1·46 to 1·53. It is to be observed, however, that the actual specific gravity of wood varies, in the same variety, with its age, the nature of the soil upon which it has been grown, and its site in relation to the prevailing wind; also, that young woods are specifically heavier than the older ones. The condition of the woods when the preceding densities were taken is not stated; the following table, based on different authorities, is therefore more satisfactory :—

Variety of Wood.	Hartig.		Wernek.	Winkler.	Mushenbroek
	I. Recently Felled.	II. Dried in Air.	III. Strongly Dried.	IV. Strongly Dried.	V.
Common Oak, ...	1·0754	0·7075	0·6141	0·663	0·929
Pedicle Oak, ...	1·0494	0·6777	..	0·663	..
White Willow	0·9859	0·4873	0·4464	0·457	0·585
Beech, ...	0·9822	0·5907	0·5422	0·560	0·852
Elm, ...	0·9476	0·5474	0·5788	0·518	0·600
Hornbeam, ...	0·9452	0·7695	..	0·691	..
Larch, ...	0·9205	0·4735	..	0·441	..
Scotch Fir, ...	0·9121	0·5502	0·4205	0·485	..
Sycamore, ...	0·9036	0·6592	0·5779	0·618	0·755
Ash, ...	0·9036	0·6440	0·6337	0·619	0·734
Birch, ...	0·9012	0·5550	0·5699	0·598	..
Mountain Ash, ...	0·8993	0·4716	..	0·552	..
Fir, ...	0·8941	0·5910	0·4303	0·493	0·550
Silver Fir, ...	0·8699	0·5749	0·3838	0·434	..
Wild Service, ...	0·8633	0·5001	..	0·549	0·874
Horse Chestnut, ..	0·8614	0·4390	..	..	..
Alder, ...	0·8571	0·3656	..	0·443	0·800
Lime, ...	0·8170	0·4302	0·3480	0·431	0·604
Black Poplar	0·7795	0·3931	..	0·346	0·383
Aspen, ...	0·7654	0·4302	..	0·418	..
Italian Poplar, ...	0·7634	0·3931	0·4402	..	..
Ground Willow, ..	0·7155	0·5289	..	0·501	..

The numbers given by each of the authorities in the preceding table can only be received as an approximation to the truth; but Winkler's are probably the most trustworthy, because, in making his observations, the bulk of wood—one cubic inch—was the same in every instance, and the specimens were exposed in a heated chamber during six months, so that all contained an equal amount of water at the time of the experiment.

The principal difficulty experienced in attempting to determine the gravity of different kinds of wood, arises from the absorption of air into the pores and its subsequent expulsion. Marcus Bull in his experiments removed this cause of error to a great extent, by coating the samples with a varnish having the same gravity as water. This insured the retention of the air in the pores, and admitted of arriving at a true approximation, although this appeared less than when quantities of the enclosed air were allowed to escape, as generally happens on immersing dried wood in water. Before citing his results, however, the appended table, containing Karmarsh's recent determinations, is placed before the reader, as affording a comparative view of the specific gravity of different kinds of wood in the green and in the dried state, with the mean weight of one cubic foot of the dried material :—

Variety of Wood.	Specific Gravity.				Mean weight of one cubic foot of Air-dried Wood in pounds.
	In the Green State.		In the Dried State.		
	Limits.	Mean.	Limits.	Mean.	
Maple,	0·843 .. 0·911	0·893	0·645 .. 0·750	0·697	37 pounds.
Apple,	0·960 .. 1·137	1·018	0·734 .. 0·793	0·763	41 "
Birch,	0·851 .. 0·987	0·919	0·688 .. 0·738	0·713	38 "
Pear,	.. .. ..	..	0·616 .. 0·732	0·689	37 "
Red Beech,	0·852 .. 1·109	0·980	0·690 .. 0·852	0·771	41 "
Box,	.. .. ..	..	0·912 .. 1·031	0·971	52 "
Cedar,	.. .. ..	..	0·561 .. 0·575	0·568	30 "
Ebony,	.. .. ..	..	1·187 .. 1·331	1·259	67 "
Oak,	0·885 .. 1·062	0·973	0·650 .. 0·920	0·785	42 "
Alder,	0·809 .. 0·994	0·901	0·505 .. 0·680	0·592	31 "
Ash,	0·778 .. 0·927	0·852	0·540 .. 0·845	0·6[illegible]2	37 "
Pine,	0·848 .. 0·993	0·920	0·454 .. 0·481	0·467	25 "
Scotch Fir,	0·811 .. 1·005	0·908	.. ..	..	"
Larch,	0·694 .. 0·924	0·809	0·565	0·565	30 "
Lime,	0·710 .. 0·878	0·794	0·559 .. 0·604	0·581	31 "
Poplar,	0·758 .. 0·956	0·857	0·383 .. 0·591	0·487	26 "
Guaiac,	.. .. ..	..	1·263 .. 1·342	1·302	69 "
Silver Fir,	0·894	0·894	0·498 .. 0·746	0·622	33 "
Elm,	0·878 .. 0·941	0·909	0·568 .. 0·671	0·619	33 "
Willow,	0·838 .. 0·855	0·846	0·392 .. 0·530	0·461	25 "
White Beech,	0·939 .. 1·137	1·038	0·728 .. 0·790	0·759	40 "

The Hanoverian pound, which is that given in the preceding table, is equivalent to 1·031114 English. It may be seen from this table, that most of the results show the specific gravity of the samples examined to be about half that of water. A fair average of the value of wood, subjected to desiccation in open sheds, can only be arrived at by ascertaining the weight. MARCUS BULL has shown that, for every fifty-six parts of actual wood contained in an ordinary stack, there are forty-four of unoccupied space. In prosecuting his inquiries into this subject, he determined the real amount of matter in a given bulk of wood, the tabulated specific gravity having been previously ascertained by coating the wood with varnish as already stated:—

Species of Wood.	Lbs. avoirdupois in a cubic metre = 35·3 cubic feet English.	Lbs. avoirdupois in a cubic foot.	Specific Gravity.
Walnut—with scaly bark,	1227·6	34·7	1·000
White Oak—Chestnut,	1075·8	30·5	0·885
American Ash,	919·4	26·0	0·772
Beech,	880·0	24·9	0·724
Hornbeam,	875·6	24·8	0·720
American Elm	704·0	19·9	0·580
Yellow Pine	668·0	18·9	0·551
Birch—Poplar-leaved	647·6	18·3	0·530
American Horse Chestnut,	633·6	17·9	..
Italian Poplar,	481·8	13·6	..

The following results obtained by M. BERTHIER may also be useful:—

Nature of the Wood.	State of the Wood.	Weight of a cubic metre = 35·317 English cubic feet in pounds avoirdupois.	Weight of a cubic foot in pounds.
Forest Oak from the environs of Moulons,	A year cut in cleft logs,	826·9	26
" " "	Cut in four,	1135·6	34
Oak of the forest of Monadier, near Moulons,	Large wood cut for three years' cleft,	875·0	26·3
" " "	Cut in four,	1059·4	33
Oak of the environs of Cahors,	A year cut,	1157·6	36
Charring Oak,	Same—length thirty inches,	485·1 to 577·7	15 to 18
Beech of the neighborhood of Moulons,	Cut in large billets,	882·0	30
" " "	Partly worm-eaten,	826·8	26
Aspen for charring,	....	419 to 485·1	13 to 15
Birch from the neighborhood of Moulons,	In very large billets,	970·2	30
Fir from Mou[illegible]ers,	In large wood,	661·5 to 749·7	21 to 22

Even these numbers do not take cognizance of the water which is present in air-dried wood to the extent of a quarter of its weight; hence, to find the real value in ligneous matter, these results should be multiplied by three-fourths.

At best, the density of wood leads but to a very vague and unsatisfactory conclusion regarding its heating power, although the fact of one sample being better than another in this respect may generally be inferred from its greater specific weight, which is a proof that it contains more carbonaceous matter in the same bulk. The condition of equal dryness, however, should not be overlooked, as without taking this into consideration the gravity deduced would be erroneous. From two-fifths to one-half the bulk of a stack of wood is interstitial space, even when the logs are of fair proportions; this is, however, much increased when small or crooked billets enter into its composition. Hence, in a stack, the per centage of solid matter compared with the bulk of the whole is very much less than that given in BULL's table. At the same time, it is only the quantity of woody matter that renders the material valuable as fuel; and a much nearer approximation to this can be arrived at when it is purchased by weight, than if the content is estimated by measurement. When, however, the purchaser is compelled to adopt the latter course, he should remember that the largest and straightest, as also the driest and densest varieties, are the surest to afford him an adequate value; the light, soft, and green woods not possessing sufficient matter to endue them with heating power in proportion to their bulk.

VALUE OF DIFFERENT KINDS OF WOOD AS FUEL.—Very many considerations are to be taken into account in selecting wood as fuel—namely, the quantity of heat to be generated, the distance to which its effects are required to extend, and the length of time that the temperature must be sustained.

When soft light woods are burned, their action is brisk but transitory, their porosity favoring the rapid evolution of the volatile inflammable gases to which a part of their substance is converted by the heat; moreover, this looseness of texture allows the transmission of air freely through the mass of charcoal left, and, consequently, effects its rapid combustion. A remarkable exception indeed is cork-wood, which, although very light, affords more charcoal proportionally than any other species. When the wood is hard and compact, the heat cannot traverse it so freely; and the result is, that the interior portions undergo a kind of consecutive distillation, the volatile matters being slowly disengaged from the surface. When these have produced their effect, a charcoal remains of a dense and close character, weighing fifteen or twenty times more than that which light wood produces. Submitted to combustion, the charcoal from dense wood burns much more slowly, owing to the smaller surface which it presents to the air, than that from the softer kinds. These facts lead to the conclusion, that the principal effect of soft light woods is produced by the flame, the charcoal they afford being comparatively of little value. The contrary is the case with heavy woods, the flame from which is feeble compared with the others; but their charcoal is far superior, and more than counterbalances the difference.

It has been shown, in a preceding part of this article, that incandescent charcoal is very much superior to flame in radiating power; or, in other words, the quantity of caloric given off from charcoal is considerably greater than that emitted from flame; and as the denser woods produce, for equal weights, a much larger amount of charcoal than the lighter kinds, it follows that much more heat will result from the former. Nevertheless, although light woods are less adapted for all heating operations in which radiation plays an important part, yet they may be employed with advantage where it is required to communicate an elevated temperature to objects distant from the fire-place, or a uniform temperature to solid bodies in large masses. Such are the reasons of their being preferred for glass-works, porcelain manufactories, *et cetera;* and even if a naturally dense material be employed for these purposes, it is brought to a suitable state by splitting it up into thin pieces, so as to render the combustion quicker, or to avoid the introduction of a useless mass of air into the furnace. On the contrary, blocks of dense wood are preferable for the heating of boilers, and other similar purposes, because, in this case, the radiant matter is required to act directly on the surface to be heated, which communicates by contact the heat to the liquid in tho interior, through which it is then diffused by convection. The superiority of the denser over the softer woods for consumption in ordinary household fires, where radiation performs the most important part, is a fact universally recognised in practice. For stoves, also, and for heating apparatus in general, the former are found to be more advantageous, because they afford a much more regular and prolonged heat than the lighter woods, without involving the necessity of constantly adding fresh material to maintain the fire. On the other hand, apart from these considerations, the actual calorific effect of the same weight of dense and light wood is nearly equal. This has been proved experimentally by MARCUS BULL. Operating with a stove so constructed as to lose the least possible amount of heat, he found that the widest proportions between numerous specimens were as fifteen to sixteen.

In England, where wood is scarce and coal fields are numerous and extensive, the former is little employed as a fuel, except for some special purposes: but this is not the case in all other nations, and some European states in particular are almost entirely dependent upon wood for common consumption. On the Continent, firewood is divided into three kinds, namely, *new wood*, *float wood*, and *peeled wood.* The first is that which has been conveyed by boat or waggon from the forest to the place of its consumption; the second, that which has been floated upon the waters in the form of rafts, a mode of conveyance which causes a considerable quantity to be submerged during the passage; lastly, the peeled wood is limited to oak and certain other species, the barks of which have been removed for the sake of the principle they contain: it is generally composed of the smaller branches, and used in dwellings. Much of the value of the floated wood is lost by its submergence in the water, and this, to a great extent, counteracts the advantages of cheap transport. The loss arises from the solution of the principle of the sap in the water, and is visible in the density as well as in the volume, sometimes amounting to one pound per cubic foot.

SOLID CONSTITUENTS OF WOOD.—Fibrous matter, water, sap, and mineral salts, are the proximate principles of wood of every description. The amount of water contained in different woods has already received a share of attention, and as the sap is of a different nature in every species, to enlarge upon it in all its varieties would unduly prolong this article. The further explanation of the proximate principles of wood will, therefore, be confined to the cellulose, lignin, or woody fibre, and the mineral constituents.

Lignin.—Woody Fibre or Lignin constitutes, as already stated, the main bulk of trees, and mostly all plants, varying in texture from the delicate and friable pith to the hard shells of the seeds, and the more dense and indurated vegetal ivory or perisperm of the seeds of the phytelephas. Regarded in conjunction with the mineral matters, it may be termed the skeleton of their structure, wherein is contained the various secretions and other principles. When the fine raspings of wood are treated successively with boiling alcohol, water, weak solutions of potassa, dilute hydrochloric acid, and ultimately boiled repeatedly with distilled water, there remains a white substance, which, when dried at 212°, is this *cellulose* or *lignin.* Not only may it be procured from the hard wood; but the pith of trees and plants yields it even more freely. If this pith be reduced by rasping, and then washed successively with hot and cold water, digesting in a weak solution of potassa, and afterwards subjecting it to the action of chlorine gas, the fibrin will be readily obtained. To complete the process, however, the digestion with the alkali is repeated, and this is succeeded by another with acetic acid, when, after affusing well with distilled water, and drying, a very pure lignin results. Many substances—such, for instance, as linen, cotton, paper, *et cetera*—afford lignin in a much purer state than wood, owing to the treatment which the fibre of flax and cotton undergoes to prepare it for those manufactures.

Pure lignin is tasteless, colorless, and insoluble in water, alcohol, ether, and essential oils; it has a specific gravity of 1·5, and is resolvable into other compounds by acids, such as nitric and sulphuric. The latter, in a concentrated state, converts it first into gum or dextrin, which may be afterwards resolved into grape-sugar. To effect this, one hundred parts of lignin—or clean bleached cotton or linen, answers the purpose—are treated with one hundred and forty of concentrated sulphuric acid in such a manner as to avoid the evolution of heat, or any charring; the mixture will readily admit of being triturated into a magma, which is soluble in water. By treating the aqueous solution of this mucilaginous matter with chalk, and straining or filtering, a liquid is obtained, from which alcohol separates a gummy precipitate; and this, after being elutriated with the spirit, and then dissolved in water acidulated with sulphuric acid, and boiled for some time, passes into grape-sugar.

It might be inferred from these results, that strong sulphuric acid converts lignin into amidin and dextrin; and, finally, into glucose or grape-sugar; yet the evidence in proof of the first change is not very distinct, although, on the application of the sulphuric acid to the substance, if a solution of iodine be added, a deep blue tint will appear. To show that the transformation to starch is effected, Schleiden directs that clean cotton wool be wetted with water, then squeezed dry, and afterwards spread upon a flat dish, and moistened with a mixture of three parts of sulphuric acid and one of water; after about half a minute, an aqueous solution of iodine is added. With this treatment the blue iodide of starch does not fail to make its appearance.

Sulphuric acid reacts with great vigor upon wood and lignin, especially when heat is applied, giving rise to sulphurous, acetic, and formic acids, besides producing a black magma, from which water washes out those bodies, and leaves the carbonaceous residue to the extent of forty-three per cent. of the wood employed.

Nitric acid, in the concentrated state, decomposes lignin, changing it into the peculiar body xyloidin, which has nearly the same characteristics as that obtained from starch by similar treatment. The *gun-cotton* of Schönbein, which is prepared by immersing cotton wool for a short time in equal parts of concentrated sulphuric and nitric acids, and washing under a stream of water and drying, is probably either a peroxide or a nitrate of lignin.

Hydrochloric acid, on being boiled with lignin, turns red, and ultimately brown. In the solid state, it becomes black, but does not dissolve in the acid. When this substance is washed and dried, it burns with flame, showing that it is only modified lignin, and not entirely carbonized. Fused potassa, or a strong solution of this alkali, changes a portion of the matter into oxalic and acetic acids, which combine with the base; the alkaline liquor, when treated with acids, parts with a modified lignin which is blued by iodine.

From what has been said of the behavior of lignin, more especially with sulphuric acid, it may be inferred that its composition is analogous to that of amylaceous compounds, or, in other words, that it is made up of the elements, carbon, hydrogen, and oxygen; the latter two being in that proportion in which they form water. Gay-Lussac and Thenard were the first to arrive at the conclusion that this proportion existed between these two elements, and the analyses of Prout and others corroborated this view of the subject. To show the identity of lignin in the extensive circle of plants in which it is found, was a work undertaken and successfully accomplished by Prout—not, however, by having recourse to numerous analyses of the principle prepared from different plants, but by taking two products of very opposite physical characteristics, and submitting them to ultimate analysis. These were portions of lignin from the *box* and *willow*; the former being one of the densest, and the latter one of the lightest species of woods. After preparing the lignin by repeated treatments with boiling water and alcohol, *et cetera*, it was submitted, after desiccation in air, to analysis, which gave the following numbers:—

	Centesimally.	
	Box.	Willow.
Carbon,	42·7	42·6
Water,	57·3	57·4
	100·0	100·0

By exposing the lignin thus analysed to a temperature of 212°, as long as loss was sustained, it was found that 14·6 per cent. of the weight of the box and 14·4 per cent. of the willow disappeared. Upon examination, the dried substance showed the annexed proportions :—

	Centesimally.	
	Box.	Willow.
Carbon,	50	49·8
Willow,	50	50·2
	100	100·0

By comparing these numbers with the figures given by GAY-LUSSAC and THENARD, as representing the composition of the lignin of beech and oak, namely :—

	Oak.	Beech.
Carbon,	52·53	51·45
Water,	47·47	48·55

or specifying the quantity of the water-producing elements thus :—

Carbon,	52·53	51·45
Hydrogen,	5·27	5·41
Oxygen,	42·20	43·14

the coincidence of composition will become apparent. LIEBIG assumes, from the analysis of GAY-LUSSAC and THENARD, that the formula is C_{36} H_{22} O_{22}; but calculating from the numbers obtained by PROUT, it is C_{36} H_{24} O_{24}.

By the action of heat, the hydrogen and oxygen in this body are made to unite, and, consequently, so far as the estimation of the value of lignin as a fuel is measured by the oxygen assimilated, they play no part, although it must be admitted that a certain quantity of caloric is disengaged by the chemical action which is produced by their union, notwithstanding that this may be rendered latent by the dispersion of the water so generated in the form of steam. It is, therefore, the carbon which operates in developing caloric by combining with oxygen, of which one hundred and thirty-eight parts are required to effect the conversion of one hundred parts of wood, represented by 52 of carbon, into carbonic acid. The caloric produced in this reaction is capable of melting 4,888 parts of ice, or of raising 3,666 parts of water from 32° to 212°. With these theoretical deductions, the practical results of RUMFORD and HASSENFRATZ are in perfect accordance, giving 3,600 to 3,680, as the equivalent for dry woods. It must be observed, however, that all the heat is not produced by the carbon of lignin, as assumed in the above calculation; because the principle of the sap is retained. This, however, approaches so near in composition to woody fibre, and its quantity is so minute, that it does not cause any remarkable difference between the results of the ultimate analysis of dry wood and pure lignin, as the following table drawn up from the determinations of SCHÖDLER and PETERSON shows :—

Species of Wood.	Carbon.	Hydrogen.	Oxygen.
Pure woody fibre,	52·65	5·25	42·10
Quercus robur.	49·43	6·07	44·50
Fraxinus excelsior,	49·36	6·075	44·57
Acer campestris,	49·80	6·31	43·89
Fagus sylvatica,	48·53	6·30	45·17
Betula alba,	48·60	6·375	45·02
Ulmus campestris,	50·19	6·425	43·39
Populus nigra,	49·70	6·31	43·99
Tilia europæa,	49·41	6·86	43·73
Salix fragilis,	48·44	6·36	44·80
Pinus abies,	49·95	6·41	43·65
Pinus picea,	49·59	6·38	44·02
Pinus sylvestris,	49·94	6·25	43·31
Pinus larix,	50·11	6·31	43·58

It should be remembered, however, that the ash which, as will be presently seen, averages from one per cent. to a much higher proportion, has not here been taken into account, and, consequently, that the difference is greater than it would be, if the mineral ingredients were left out. CHEVANDIER has investigated some woods, taking cognizance of this fact, and the several specimens being dried at 284°, afforded the following results :—

ELEMENTARY COMPOSITION OF SOLID WOOD AFTER DEDUCTING THE ASH.

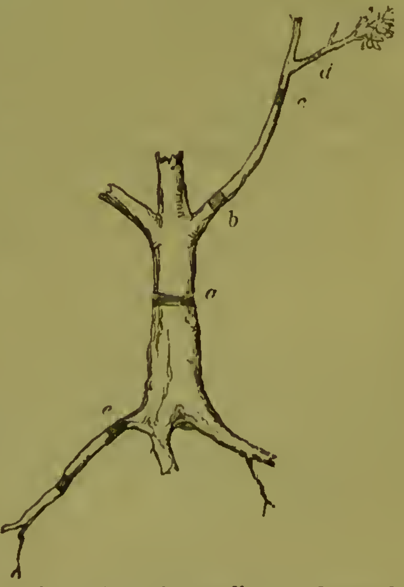
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses
Beech,	49·89	6·07	43·11	0·93	7
Oak,	50·64	6·03	42·05	1·28	5
Birch,	50·61	6·23	42·04	1·12	4
Aspen,	50·31	6·32	42·39	0·98	3
Willow,	51·75	6·19	41·08	0·98	2

ELEMENTARY COMPOSITION OF BRUSHWOOD AND BRANCHES AFTER DEDUCTING THE ASH.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses
Beech,	50·08	6·23	41·61	1·08	8
Oak,	50·89	6·16	41·94	1·01	4
Birch,	51·93	6·31	40·69	1·07	3
Aspen,	51·02	6·28	41·65	1·05	2
Willow,	54·03	6·56	37·93	1·48	2

On the whole, it appears from what has been stated, that carbon, oxygen, hydrogen, and nitrogen, are the essential ultimate elements of vegetal products, and that the proportion in which they combine is very nearly the same in different plants. It is, therefore, not a little remarkable, that the composition of even the same plants is found to vary slightly in different parts. This might be expected in regard to the distinct organs—such as the pith, the wood, the bark, and the leaves—but not in regard to different complete portions of the same organic structure. Even in the latter, however, a sensible variation exists in the root, the trunk, and larger or smaller branches. M. VIOLETTE examined various portions of the completely organized structure of the same tree, with the view of determining this point. The subject of his experiments was a healthy cherry-tree, thirty years old, which was carefully dug up in the month of October, taking care to preserve the roots and rootlets entire and without injury. Samples were taken from the trunk, the branches, and the roots, as represented in Fig. 16, at *a*, *b*, *c*, *d*, *e*, *f*, *g*—all cut of equal thickness and enclosed in paper capsules, which were deposited during five hours in the bottom of a receiver, in which a current of steam from the boiler was made to circulate. By this exposure to air and to the temperature of about 172°, they all acquired an equal desic-

Fig. 16.



cation, and, after this treatment, they were well dried by enclosing them in flasks. The results which were arrived at by submitting these woods to analyses are subjoined, and the operator states that they were not accepted till the repetition of the process corroborated them :—

COMPOSITION OF WOOD CUT FROM VARIOUS PARTS OF THE SAME TREE.

Nature of Wood.		Elementary substances found in 100 parts of wood. Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.
Leaves,		45·015	6·971	40·910	7·118
Small branch,	Bark,	52·496	7·312	36·737	3·454
	Wood,	48·359	6·605	44·730	0·304
Middle-sized do.	Bark,	48·855	6·342	41·121	3·682
	Wood,	49·902	6·607	43·356	0·134
Large do.,	Bark,	46·871	5·570	44·656	2·903
	Wood,	48·003	6·472	45·170	0·354
Trunk,	Bark,	46·267	5·930	44·755	2·657
	Wood,	48·925	6·460	44·319	0·296
Large root,	Bark,	49·085	6·024	48·761	1·129
	Wood,	49·324	6·286	44·108	0·231
Middle-sized do.	Bark,	50·367	6·039	41·920	1·643
	Wood,	47·390	6·259	46·126	0·223
Rootlet, with branch,		45·063	5·036	43·503	5·007

Mineral Constituents.—When wood is burned, it always leaves a certain amount of residue or ash, which consists of various alkaline and earthy salts that have been taken up from the soil with the sap. The bases or metallic oxides of this ash are potassa, soda, lime, oxide of iron, and sometimes oxide of manganese; one or more of which are united with silicic, carbonic, sulphuric, and phosphoric acids, chlorine and sulphur. All woods have not the same per centage of inorganic matter contained in them, and, as may be seen in the preceding table, it varies remarkably in different parts of the same tree, and also with its age.

According to SAUSSURE, the quantity of ash yielded by—

1000 parts of barked young oak branches was....	4 parts.
1000 parts of their bark,	60 "
1000 parts of an oak trunk 56 feet diameter,	2 "
1000 parts of its bark,	60 "

BERTHIER, KARSTEN, CHEVANDIER, and others, have likewise directed their attention to this subject, employing air-dried wood as the subject of their experiments. The results are appended :—

ASH IN A HUNDRED PARTS.

	Berthier.	Karsten.		Chevandier.		
		In young wood	In old wood.	Solid stem wood.	Wood of branches.	Brush-wood
Silver fir—*Pinus picea*,	0·83	0·15	0·15	—	—	—
Birch,	1·00	0·25	0·30	0·57	1·00	0·48
Scotch fir, *Pinus sylvestris*	1·24	0·12	0·15	—	—	—
Oak,	2·50	0·15	0·11	1·94	1·49	1·32
Lime,	5·00	0·40	—	—	—	—
Fir—*Pinus abies*,	—	0·23	0·25	—	—	—
White beech,	—	0·32	0·35	0·73	1·54	0·72
Alder,	—	0·35	0·40	—	—	—
Red beech,	—	0·38	0·40	—	—	—
Aspen,	—	—	—	1·49	2·38	—
Willow,	—	—	—	2·94	3·66	—

ACTION OF HEAT ON WOOD.—Having explained the constituents of wood, it remains now to examine the effects of heat upon it. As the tendency of caloric is to subvert the power of the existing affinity between the elements of complex bodies, as well as to change their physical appearance, the simpler the substances submitted to its action—that is, the fewer elements composing them—the greater is the force with which they are held in combination, and the better do they resist the influence of caloric. When several bodies enter into the composition of a substance, it readily yields to the decomposing effects of fire, especially if the constituents have an affinity for one another, whereby simpler combinations are produced. Products of organic growth are generally of this class, as they include several elementary bodies which have a remarkable tendency to arrange themselves into simpler and more permanent compounds. Some of the ingredients of these bodies are of a volatile nature; hence, as soon as the force of the heat applied overbalances that of the affinity which binds them together in the peculiar state in which the vitality of the plant arranges them, they assimilate and disperse, whilst others are left in the solid state. When the matters submitted to the action of heat are out of contact with air or oxygen, the quantity and number of the compounds formed depend, for the most part, upon the intensity of the temperature applied; but when oxygen or air is admitted, and the action of the heat is still exerted, the bodies, already modified, will undergo another change, from which will result compounds of the simplest and most permanent character. The latter transformation is always accompanied by the phenomena of combustion, whilst the former is termed dry distillation.

The constituents of organic matters, acted upon by heat in the presence of air or oxygen, unite with the latter element, and form with it the simplest and most stable compounds which it is possible for them to enter into. This is shown in the conversion of the carbon, hydrogen, and oxygen of such bodies into carbonic acid, CO_2, and water, HO—two of the simplest, and at the same time most permanent combinations. In the other method of acting with heat upon organic substances—that is to say, in close vessels or out of contact with air—the results are by no means so simple as those just described; because the conditions necessary for caloric to exert its full effect upon them are not supplied; and hence, although the compounds formed are not so complex, and are more permanent than those from which they have been generated, yet they are far from being the simplest and the most persistent.

From the moment when the decomposing agency of heat begins to overcome the existing affinity of the elements in the organic body, three circumstances concur, either to multiply the formation of distinct but definite compounds, or to yield particular ones in larger quantities: these are, as already intimated, the temperature; the natural affinity of the existing elements, more especially at the moment of their liberation in the nascent state; and, lastly, their volatility. The effects of the temperature are first directed to the expulsion of oxygen and hydrogen, two elements which, from their permanently gaseous nature, are disengaged; they have, however, a very powerful affinity for one another, and, consequently, at the instant of their liberation, this affinity is exerted, and they pass off, in conjunction, as water. When the two gases are present in that proportion in which they constitute water, a very low temperature, comparatively, will be sufficient to bring about their separation from the burning body in the manner indicated; but, on the other hand, if they be contained in a different proportion, then will the excess of the one or the other, at the instant of its liberation, attack the more fixed element—carbon—and give rise either to permanent gases, such as light carbide of hydrogen and olefiant gas, or to oily products of an analogous constitution.

Products of the Combustion of Ligneous Matter.—The number and nature of the bodies which, by a proper management of temperature, might thus be produced are still open to research. Those which have been identified are water, ammonia, acetic acid, pyroxylic spirit, or wood naphtha, and a mixture of resins and ethereal oils, denominated tar. By submitting the tar, especially if derived from coal, to further distillation and various other chemical agencies, it is resolved into a variety of bodies; such as paraffin, picamar, creosote, kapnomor, pitacall, and naphthaline—compounds discovered by REICHENBACH—pyrogenous resin and numerous oils, besides coal-tar naphtha, which contains various basic and acid bodies. In addition to these, a number of gaseous compounds is produced, such as carbonic acid and carbonic oxide, light carbide of hydrogen, *et cetera.* The nature of the products will vary according as oxygen or hydrogen preponderates in a fuel; thus, when it is rich in oxygen, the greater will be the production of carbonic oxide and carbonic acid, and the formation of hydrogen compounds will be limited, whereas, if hydrogen be in excess, the latter will be most abundant. How large soever the proportion of both elements may be, it will be insufficient to eliminate the whole of the carbon in the substance; hence, when vegetal matters are subjected to destructive distillation in close vessels, a residuary charcoal is always left, which, if wood, compressed peat, and such like bodies be operated upon, possesses the same form as the original substance. The carbon from most kinds of the denser coals does not retain this form, owing to their partial fusion under the influence of the heat, which produces an amorphous mass. Different names have been given to these residues; thus, what is left after the distillation of wood or peat is called *charcoal,* whilst that manufactured from coal is termed *coke.*

Charcoal and Coke.—The preparation of both these substances has become an important manufacture, as well for the sake of the by-products which are obtained in the operation, as for the carbonaceous matter itself. Carbon in some convenient form is of vast importance in the industrial arts, where great local heat is required. It has been already shown that this high temperature cannot be attained with the use of such substances as contain oxygen and hydrogen in definite proportions, since much of the heat which is produced by the ignition of such materials is necessary to disengage the volatile bodies to which they give rise, and when these are liberated, the combustion is only partial; besides, the caloric which results in this case cannot well be concentrated, and cannot be rendered very efficacious by radiation. It is only charcoal, and such bodies as will develop the greatest amount of heat from the smallest possible extent of surface, that can be employed with advantage in such operations as the smelting of metals, especially iron, and for the purposes of railway transport, *et cetera.*

Not only is carbon valuable as a fuel, it is likewise highly serviceable in many other respects; its uses, as a disinfectant, have been given in Vol. I., p. 563; it is likewise employed as an absorbent of many gaseous bodies, for depurating sirups and extracts, and as a manure. It is chiefly, however, in connection with its application as a fuel, and its superior heating effects, that the various methods of preparing it will be here detailed.

Carbon, of which charcoal, coke, *et cetera,* are modifications, is known in its native purity *in the diamond,* although, as may be supposed, the quantity of it found in this form is very small. The Ghauts in India, more especially Golconda, Borneo, and the Brazils, furnish this precious gem. In this state it possesses remarkable transparency, brilliancy, and hardness, to such a degree that in no one of these attributes has it a compeer. Its specific gravity is 3·336; it may be burned in an atmosphere of oxygen gas, or in the air, under the influence of a very high temperature, when it is converted into carbonic acid; and ROGERS, by acting upon it in a finely divided state with bichromate of potassa and sulphuric acid, found that it is completely converted into this gas. With a Bunsen's battery of one hundred plates, it may be fused into a mass resembling very compact coke.

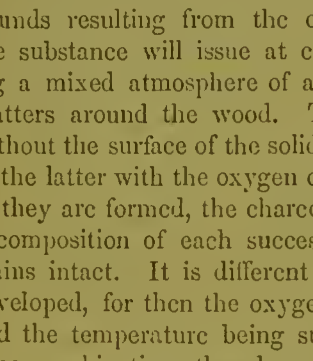
A charcoal approaching the diamond in purity, though partaking of none of those qualities which render the latter so valuable, is prepared by heating non-nitrogenous matters, such as sugar, dextrin, and the like, to redness in close vessels; or by passing the vapor of alcohol, ether, or some carbonaceous oils, through tubes heated to whiteness. In either case, a very pure form of carbon is left. As obtained by the latter process, charcoal is a brittle, black, insoluble, inodorous, and tasteless substance, capable of conducting electricity with freedom, but obstructing the passage of heat in a remarkable manner. It is unaffected by air or moisture, a quality taken advantage of in the construction of charring piles, so that they may resist the bad effects of moisture; also, in scorching the interior surface of casks and barrels destined for holding water and such liquids, both that the contents may be preserved wholesome and pure, and that the soundness of the vessel may be secured. In a pure state, it is infusible, or only fused in a slight degree by the greatest known temperatures. As stated in Vol. I., p. 563, it absorbs many gases in large quantities, has the quality of removing many alkaloids and bitter principles from their solutions, and latterly has been introduced by Dr. STENHOUSE as a physico-medical agent.

PROCESSES OF CARBONIZATION.—It is known from ancient records, that the manufacture of charcoal from wood has been practised for more than two thousand years; and very little progress appears to have been made, till lately, in improving the process. Many obvious circumstances would concur to induce the carbonization of wood in early times, such as the trouble of carriage, and the facility of charring it on the spot where it was felled. It has been shown that wood, by drying, loses sometimes as much as forty to fifty per cent. of its weight; it also contracts in proportion, and if the heat be carried on to the point of charring, this contraction will reach to twenty or twenty-five per cent. of the bulk: hence the advantage obtained by this process in point of carriage. The system followed was such as to require partly the intervention of the air, and involved the destruction of a portion of the woods; the loss being greater or less in amount, according to the care bestowed and the precautions taken. The old course is still adhered to, with some slight modifications. Taken in connection with what has been already said as to the effect of heat upon wood and matters of an analogous composition, the following remarks may suffice to point out how far the admission of air and the application of an increased temperature affect the production of charcoal.

It is evident that when a piece of wood is ignited, the heat which destroys its elementary composition passes gradually inwards from the surface, till the whole is permeated, and as each successive layer of fresh fibrous matter is attacked, the volatile compounds resulting from the oxygen and hydrogen of the substance will issue at every pore, thus producing a mixed atmosphere of aqueous and inflammable matters around the wood. The combustion of these without the surface of the solid matter prevents contact of the latter with the oxygen of the air; hence, as long as they are formed, the charcoal which is left after the decomposition of each successive layer of lignin remains intact. It is different when they cease to be developed, for then the oxygen of the air is admitted, and the temperature being sufficiently elevated to induce combination, the charcoal rapidly decreases, so that, if the oxygen continue to be supplied, nothing will be left but the small quantity of mineral matters contained in the wood.

So long as the action of the heat supplied is restricted to the first stage, the results will be satisfactory; but when it enters upon the second, inconvenience and loss are occasioned. In the common process it is impossible to exclude the air altogether, as the charring of the main bulk is effected through the agency of the complete combustion of a portion of the same material in the mass; nevertheless, by regulating the quantity and direction of the current, much of the loss incidental to this method would be avoided. For instance, in the carbonizing of two pieces of wood, of the same state of dryness and having equal dimensions, in a current of air, to which the lighted extremity of one of them is presented, as shown at A, while the ignited end of the other is averted from the blast, as at B—Fig. 17—it will be found that the first of these will be speedily consumed, whereas the other, the charred portion of which is partly protected by the gases disengaged, disappears much more slowly, and sometimes leaves a residue of charcoal. Were it possible to introduce, as the distillation progressed, the parts of the second sample which was charred, into a tube or vessel where it would be excluded from the air, a much larger amount of charcoal would result. Hence it may be inferred, that in charring heaps of wood with a movable coating of mould covering it from the air, the current should be led from the furthest and coldest extremities, that the gases, as they issue, may protect the matter already decomposed from destruction; and again, that the best course would be to effect what is termed the destructive distillation of the wood, keeping the matter subjected to this process entirely out of contact of air. Such a process of decomposition may be carried out in close vessels, and this is the one best calculated to afford the largest yield of charcoal; besides, by a little additional care and management, the various other constituents of the matter operated upon and modified, so as to exist in states which are more or less valuable in other applications, can be recovered and turned to profit.

Fig. 17.



Notwithstanding that by the process of destructive distillation in close vessels, the greatest possible control is exercised over the operation; still, if the resulting charcoal be compared with the content of carbon in wood, it will be apparent that a considerable loss is sustained. According to the analysis of the samples of wood already laid before the reader, it would appear that if the elements of oxygen and hydrogen, which exist in all of them in nearly the same proportion as in water, were removed, the charcoal remaining should constitute from thirty-eight to forty, or even forty-five per cent. of its weight, but in actual workings the yield is often so low as fifteen to twenty, and under the most favorable circumstances only twenty-seven to twenty-eight per cent. of the wood are obtained. The difference between the practical yield and that which theory would indicate, is, in these cases, considerable, and is accounted for by the circumstance that the water, which is formed at a certain temperature, reacts upon the remaining charcoal, and, according to the degree of caloric which it possesses, occasions the formation of several other compounds—such as those mentioned in the two previous pages—all of which are rich in carbon, deriving this from the charcoal, to the loss of the manufactured product. These different forms of combination proceed in the order of their oxidation, the richest in oxygen being given off first, and being succeeded by others containing less of this element, till, at the conclusion of the distillation, nothing is left, and the final products are composed of carbon and hydrogen. Thus, in exposing wood to heat in close vessels, the first bodies that are observed to pass off are water and carbonic acid, followed by acetic acid and carbonic oxide. These are succeeded by a highly carbonaceous oil of a deep brown color and empyreumatic odor, which contains but little oxygen, and, lastly, carbides of hydrogen. As long as oxygen is in abundance, the latter are not generated, and also they cease in part to exist when the temperature is very high, as the oil and acetic acid are incapable of resisting a high temperature without being mutually decomposed, and resolved into water, carbonic acid, and carbide of hydrogen. The more oxygen and hydrogen that can be abstracted from the wood in the shape of water, the greater will be the bulk of charcoal left; and to insure this the best course is to apply a heat which is only sufficient to cause the combination of those elements, although inadequate to produce the other products of a higher temperature.

The course sometimes adopted, of submitting wood which is much saturated with moisture to the action of heat, for the purpose of charring, is disadvantageous, because the vapor of this body, passing over portions already charred and partly incandescent, transforms them into carbide of hydrogen—CH—and carbonic oxide—CO—and thus diminishes the yield of solid matter; indeed, if this decomposition were thoroughly effected, there would not be as much material as would supply carbon for this end. Woods, therefore, which are treated for the purpose of obtaining the largest amount of carbon or charcoal from them, ought to be well exsiccated, so as to be divested of extraneous moisture, and then the temperature should be so controlled that the material will not attain a red heat, for, under the latter circumstances, the water produced from the elements of the wood would react in the manner above mentioned, to the detriment of the operation. M. KARSTEN made some experiments, with the view of ascertaining the relative effect of a low and high temperature, and found that if chips of wood are exposed for a long time to a heat of 300°, they will ultimately cease to lose weight. The loss sustained when air-dried wood is so treated amounts to sixty-five or seventy per cent., but when the material is first desiccated at the temperature of the water-bath, the utmost limits are from fifty-six to fifty-nine per cent. The residue in either case resembles charcoal in appearance, and was regarded as such by RUMFORD, who considered it as the skeleton of the plants; but KARSTEN has shown that it is but a modification of woody fibre, still holding matters which, when subjected to a high temperature, pass off as gases. However, the product from the application of a high heat is very different from that obtained when a low progressive one is applied, as shown by the results of KARSTEN'S experiments in the subjoined table, to which are annexed the numbers given by STOLZE and WINKLER. The wood taken as the subject of experiment by KARSTEN was dried in air, and that which WINKLER operated upon was exsiccated in a hot room, whilst STOLZE torrefied his at 212°.

TABLE SHOWING THE PRODUCE OF CHARCOAL AT HIGH AND LOW TEMPERATURES:—

Species of Wood.	By the quick process of charring. Karsten	By the slow process of charring. Karsten	Stolze.	Winkler.
Young Oak,	16·54	25·60	26·1	22·8
Old do.,	15·91	25·71		
Young Red Beech,	14·87	25·87	24·6	17·8
Old do.,	14·15	26·15		
Young White Beech,	13·12	25·22	23·8	
Old do.,	13·65	26·45		
Young Alder,	14·45	25·65		
Old do.,	15·30	25·65		
Young Birch,	13·05	25·05	24·4	17·6
Poplar,	—	—	23·8	17·7
Old Birch,	12·20	24·70	24·4	17·6
Birch 100 years old, well preserved,	12·15	25·10		
Young Deal—Pinus Picea D.,	14·25	25·25	23·4	20·6
Old do.,	14·05	25·00		
Young Fir—Pinus Abies D.,	16·22	27·72	21·5	20·1
Old do.,	15·35	24·75		
Young Pine—Pinus Sylvestris,	15·52	26·07	23·7	
Old do.,	13·75	25·95		
Lime,	13·30	24·60	22·8	16·2
Ash,	—	—	22·1	19·4
Willow,	—	—	22·2	15·0
Rye Straw,	13·40	24·60		
Fern Straw,	17·00	27·95		
Cane Stems,	14·65	26·45		

It will be observed at a glance that the advantage of a slow process of carbonization in regard to the production of charcoal is in some cases double, and is, therefore, so profitable in this respect, as to warrant its being resorted to upon all occasions. A slight difference exists in the proportion of charcoal which many of the woods in the foregoing table afford, although the same course was followed in their carbonization. The probable causes of these variations are, the changes of temperature which are liable to be experienced even within short periods in the course of manufacturing processes; and agreeably to this supposition, the widest range will be found between the results obtained at the high heat, where the variation was more likely to exist than in those samples charred at a low temperature. Taking the numbers in the second column of KARSTEN'S results as the maximum quantity which it is possible to obtain on the large scale, and comparing them with those which are arrived at by manufacturers who distil wood with the greatest precaution in close vessels, and who have in view the utilization of all the products resulting from the operation, this remarkable coincidence will be apparent. The general results obtained by these manufacturers may be expressed thus for one hundred parts of wood :—

Charcoal,	28 to 30
Acid and water,	28 to 30
Tar,	7 to 10
Carbonic acid, carbonic oxide, carbide of hydrogen, and uncondensed water,	37 to 30

If to these numbers the weight of wood necessary to effect the distillation, and which is generally about twelve and a half parts, be added, the results will agree well with what is arrived at in practice in burning for charcoal. In air-dried wood containing about forty-five per cent. of carbon, this element is distributed in the following manner :—

Charcoal left as residue,	30·00
,, combined in the form of acetic acid,	0·50
,, ,, in the state of tar,	6·00
,, ,, as carbonaceous gases,	3·50
,, required to effect the distillation,	5·00
	45·00

These results agree as closely as can be expected with the numbers given by theoretical calculation, assuming that there is no further disturbance of the elements beyond the union of the oxygen and hydrogen to form water, and the evaporation of this body together with the heating of the remaining charcoal to incipient incandescence, or to about 932° Fahr. Making these conditions the basis of the calculations it is found, theoretically, that to form the water from the elements in 112·5 parts of wood, and to dispel it together with the moisture in combination, which amounts to about sixty-seven and a half parts, the heat developed by the combustion of six parts of charcoal is necessary. Proceeding in the same way, it is found that to bring the residuary charcoal to the above-mentioned temperature, about 0·77 parts are required, making in all 6·77 parts. Practically, only five parts of charcoal are burned to perform this work; but, unfortunately, much of the carbon is carried away in the gases, so that the last number swells to eight and a half or nine parts of charcoal in the charring of the quantity already named. Even these figures are close enough to those deduced from theory to warrant the inference, that in the charring of wood no very considerable improvement towards producing a larger yield of carbon can be made upon the common method, by which from twenty-five to twenty-seven per cent. of the weight of the original substance is obtained.

Having thus far enlarged upon the theory of the subject, the practical operations will now be considered. The distillation of wood has already been explained under ACETIC ACID, though chiefly with reference to the production of the latter body. It is now to be considered with special reference to the yield of charcoal; and with this object in view, there are several methods of procedure, all differing, more or less, in their practical details, though they may all be classified under two methods, namely, such as require access of air, and those in which the air is excluded. The former includes all the different methods of charring in mounds, to which preference is generally given, to avoid the cost of transport. In purchasing wood for this purpose, its weight is estimated in a rough way in the cutting, and an approximate valuation of the timber, the charring wood, and brushwood, is made by ocular survey. To assist in this, tables have been drawn up to indicate the probable yield of charcoal from the variety of wood, according to its solidity, and the nature of the principles contained in it. The value of wood, as thus ascertained, is liable, however, to be affected by various causes—the difficulties in working it, the badness of the ways through which it is to be transported, and the conveniences which the locality offers for constructing a mound. In France, the price of a cord of wood consisting of seventy cubic feet is, on an average, from six to seven francs, or five shillings to five shillings and tenpence, but in the province of Champagne, where ironworks abound, the rate is higher. The purchaser of the wood usually cuts it, when too large, into suitable lengths, either by the hatchet or the saw; these lengths are about two feet when the material is to be charked in stalks, but when this process is to be carried on in heaps the logs are left about seven feet long. The workmen engaged in this business are paid from seven to ten pence per cord for cutting, and two or three pence for piling. Sometimes the wood is carbonized immediately, but generally it is left to dry for a certain period. Although the latter method is attended with an increase of interest on the outlay, still the quality and yield which the dried wood affords is more than adequate to repay this.

The site of the mound, or *meiler* as it is termed on the Continent, is carefully chosen by the charcoal maker. Some spot is generally selected which is sheltered either by a declivity or a wood from currents of wind, and at no great distance from the felled timber. The soil must be neither too damp nor very dry: in the former case, the moisture evaporated by the heat and passing over the charcoal, would at the high temperature convert much of the solid into gaseous bodies, and so occasion a loss; and in the latter, currents of air would enter through the interstitial channels, and prove as injurious as the humidity, or even more so. A spot which inclines to neither of these extremes is carefully cleared off in the summer time; and previous to erecting the meiler, if any misgiving is felt as to the fitness of the site, it is covered over with shingle or planks, and these are overlaid with charcoal powder to the depth of several inches. Having thus prepared the flooring, a stout stake is erected in the centre, having its upper end cleft crosswise at right angles: and into these incisions two logs are adjusted, forming right angles with one another in the same horizontal plane. Four logs are then inclined against the vertical post, the upper ends fitting into the angles produced by the intersection of the cross bars at the top. The floor or hearth of the meiler is then formed by placing billets of wood all round, radiating from the central post; the vacant spaces are filled with pieces of wood of smaller dimensions; and to secure the whole in the order in which they are laid, pins are fixed all round the periphery at about a foot distant from one another. Very dry wood, or such pieces as are easily ignited, are now arranged around the central post in a nearly vertical position, so as to form a truncated cone; these are enclosed by layers of billets of about equal length placed horizontally on the floor, and the vacancies filled up as before. Two or more such layers, forming concentric rings, are added to increase the diameter of the mound, as shown in the sectional drawing, Fig. 18; and these, as they are successively raised, incline at the same angle as the nucleus around the central stake, owing to the logs being all cut of the same length, according to a regulation enforced by the Forest Laws. This is advantageous, inasmuch as it offers facilities for covering the whole more firmly with the soil or mould. When raised to the proper height, the heap is rounded at the top by adjusting logs and brushwood together; and after this the whole is coated with a covering of soil from four to six inches in thickness, interposing grass, leaves, and such bodies between it and the wood. This coating does not extend to the bottom, but rests upon a layer of twigs and branches a few inches in thickness, held in their position by forked uprights—an arrangement adopted to allow of the escape of the aqueous vapors which are discharged by the first action of the heat upon the wood. Were the steam permitted to escape at the superior openings, too much draught would be produced, and more air would thus be admitted than is advantageous to the working. The base of the meiler is protected from unfavorable draughts by an armor of wicker work—as seen in Fig. 19—representing the heap ready for ignition. In this drawing, *a* denotes the quandel, *b* the aperture by which the mass is ignited, and *c* and *d* the armor surrounding the base. A few holes are left in the top and sides of the heap corresponding to the billets placed at the base. Care is taken to have the cover much more solid at the top, in proportion to the height to which the meiler is raised, so as to resist the draught which chiefly exerts its influence on this part of the heap. The mass is ignited by adding glowing charcoal to a quantity of brushwood which is placed in a channel left at the foot of the meiler for the purpose; the fire rapidly traverses to the interior and attacks the logs which are arranged round the vertical stake; when these are red-hot the upper orifices are closed, and the first stage of the operation, namely, the *sweating*, is then allowed to proceed. Much care is required to prevent a too copious disengagement of vapor at this period, which would destroy the heap; the process is going on well as long as the smoke presents the appearance of a yellowish-grey cloud. Much watery vapor is emitted at this stage, portions of which condense upon the covering of the heap, giving it the appearance of exudation. As the moisture is expelled the gaseous matter assumes a lighter grey appearance, which is the indication of the second stage of the process. The wood of the stake and portions of that surrounding it are now consumed, as well as the brushwood at the top; irregularities are, consequently, formed in the covering owing to portions of its support yielding, and openings for the escape of the products of the combustion are produced. About this period the aperture which was caused by the annular support at the base, termed the *armor*, is closed; after this, and on observing the above indications, the top part of the covering is removed as speedily as possible, the logs near the stake broken up and forced together with a long pole, and the empty space thus formed charged anew with more logs, the whole being secured under the mould as before. The entire combustion of the portion of wood in the centre, and of the smaller branches throughout the heap, now reacts upon the remainder of the logs causing their destructive distillation.

Fig. 18.

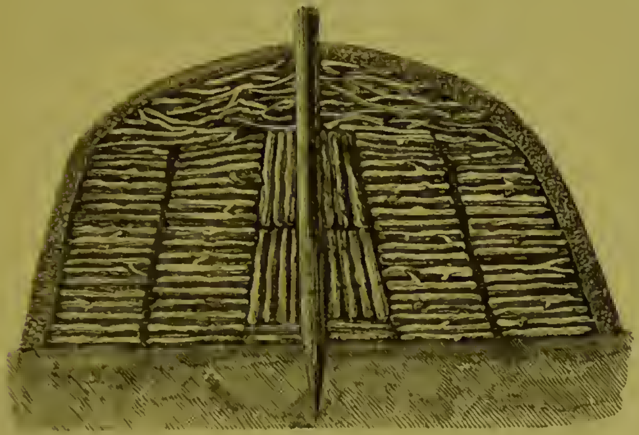
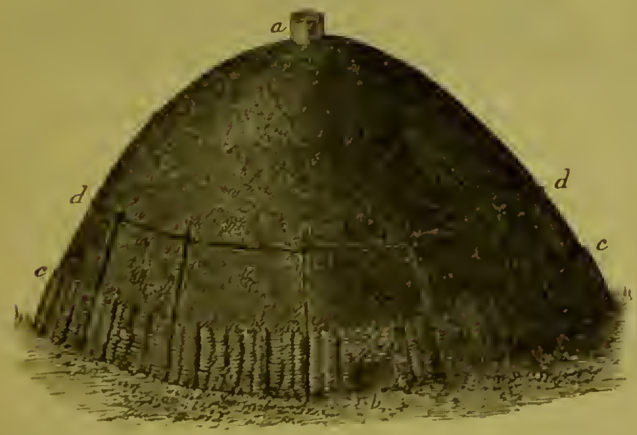


Fig. 19.



For several days the charring proceeds progressively towards the exterior of the meiler. During this time continual attention is necessary, as well in allowing the tarry vapors to issue at the base by making openings for that purpose, as in supplying air for maintaining the heat required for the charring, and checking the draught where the temperature and the combustion are too violent. As the work progresses and the wood becomes charked, the heap contracts, but this is apt to be very partial unless the workmen control the draught, by making outlets in the covering of that portion where the effect of the fire is slow, and drawing the heat to it, at the same time putting on a thicker coating where the action is likely to be too vigorous. Having done this in the upper part of the heap, it still remains to conduct the heat to the outer surface. The cooling tendency of the coating, and the condensation of water and empyreumatic matters upon it, render the ignition of the logs near the coating impossible under the circumstances hitherto stated; and if the operation were allowed to proceed, the logs in the outer ring would be only half or three-quarters burned, even when the charcoal in the interior would be overdone. To guard against this, a second series of holes must be made in the upper part of the breast of the meiler, in a line with those at the foot, but more distant; these openings need not, however, be made as high as there is wood uncharred, for the direction of the draught to this quarter will generate as much heat as will be sufficient to carbonize it, even above the temporary chimneys. From these orifices a thick black smoke is discharged, which, after a time, is succeeded by a thin blue cloud; as soon as this is observed the orifices made are closed, and others formed at a distance of two or more feet nearer the base, and the vapors allowed to issue by them till the same appearances are observed as before. According to the size of the heap and the state of completion of the work in hand, a third and fourth series of such perforations are made in the covering, and the combustion of the matter in their vicinity is allowed to proceed till the heat is intense enough to decompose their elementary arrangement, after which they are closed. When the process is finished, flames issue simultaneously from the different apertures around the heap; and should this not be general, vents are opened in other parts in order to expedite the appearance of the flame all round. When this occurs, the process is completed, and the duty of the attendant is now to extinguish the incandescent mass. Were this point overlooked, and the heap broken up before the charcoal was thoroughly cooled, no inconsiderable loss would be sustained; on the other hand, if it were left to part with its caloric spontaneously, too long a time would be required for this purpose, in consequence of carbon being a bad conductor of heat. The course adopted is to coat the whole heap with a thick layer of moist earth, and to leave it thus choked during a period which varies according to circumstances—generally twenty-four hours; if the temperature be not sufficiently reduced by this time, as much of the covering as is possible, without exposing the charcoal to air, is taken away, and replaced with another layer of the humid soil. If two coverings be given, the time allowed for its remaining on the heap is shortened.

When the whole is sufficiently cool for drawing, the covering is stripped off, and the charcoal taken and spread upon the soil in a thin bed; should any sparks remain, it is necessary to exclude the air from these parts by throwing sand upon them. Another method is practised, which, though more expeditious, is nevertheless more open to loss. It is to strip the meiler partly at the base, and by means of a hook to draw out the logs of charcoal separately and cover them instantly with sand, clay, or some such material as will readily extinguish them; water, when convenient, is employed for this purpose. When as many logs are abstracted from this opening as can be easily managed, it is quickly closed so as to prevent, as far as possible, the combustion of the incandescent charcoal; a fresh hole is then made at some distance, and the charcoal taken from it treated as before. This operation is repeated all round the base of the meiler till the whole is extinguished. Night is the best time for conducting this part of the work, as the darkness enables one to observe the smallest spark in the charcoal.

In the methods adopted in the New Forest, a different arrangement of the wood in the construction of the meiler is resorted to. The logs are placed perpendicular, or nearly so, around the central stake, or quandel, to the breadth of the pile, and one or two other rows, all in an erect position, are superimposed upon this; the top of the stack is rounded by fixing shorter logs horizontally, in the manner indicated in the sectional drawing—Fig. 20. In all the other details the working of both forms of meiler is the same, differing, however, in the manner of igniting. With the arrangement here represented, the fire is communicated from the top. The quandel being formed of three stakes fixed at the distance of a foot from one another, at which distance they are retained by introducing blocks of wood between them, the empty space is filled up with dry brushwood and half-burned charcoal. Combustion is commenced by introducing red hot coals into this part, and as fast as the light wood is consumed fresh material is supplied, until the logs of the meiler have in part undergone combustion. The regulation of the draught is attended to with all possible care, and so conducted as to induce the carbonization of the wood after the sweating, in the order represented by Fig. 21.

Fig. 20.

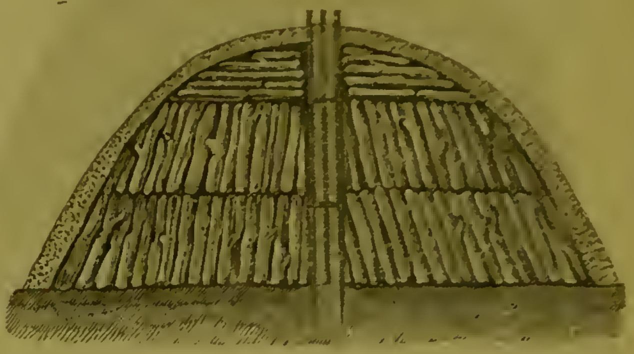
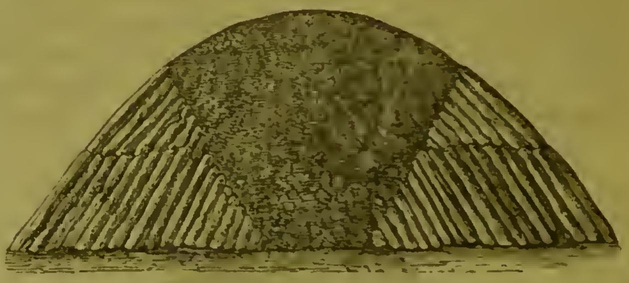


Fig. 21.



To effect this the draught must necessarily be directed from the burnt towards the unburnt portion. This is managed by forming the temporary chimneys in such positions as to draw the volatile matter from traversing the burnt portion, while the openings at the base are at some distance from that part where combustion is taking place. The effect of the fire is known by the depression of the covering, and this apprizes the attendant where the openings for the draught should be made, so as to keep it from that portion which is already carbonized. In the latter method of constructing the pile, care must be taken not to allow much vacant space between the logs, especially between the ends of the first range and those of the next. If this were neglected, the circulation of air would be too rapid, causing the fire to spread over a large surface without effecting a sufficient carbonization.

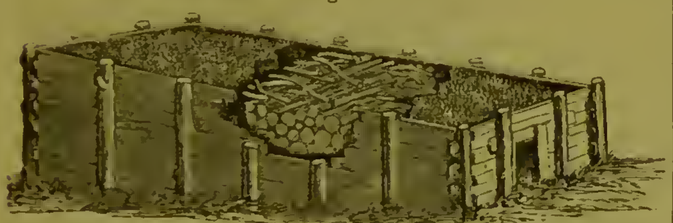
Both these forms of meiler are used generally in the forests, and perhaps it is difficult to say which is preferable. Among the Swedish burners it has been established that more charcoal is obtained when the logs are piled up horizontally, than when they are arranged in a nearly vertical position; but the charring is not so well or so readily effected. With the second or vertical method, the loss by combustion is much greater, but the quality of the charcoal produced is superior to that obtained by the other processes.

Another method of charring is in use, especially at Wienerwald, and also in mountainous districts where there is no great depth of soil, and where resinous wood is operated upon. The form of the heap or pile is shown in Fig. 22—a kind of structure termed *Haufenverkohlung*, and offering facilities of charring uncleft wood of every dimensions. When this mode is adopted, it is customary to bark the wood, in order that the fire may attack it more readily than it would do if not so prepared. The best period for depriving charcoal wood of the bark is immediately after felling, for then the operation is easy, whereas, if attempted when partly dried in the air, considerable difficulty would be experienced. Besides presenting advantages as to facility of combustion, barked wood has other qualities which ought to be taken into consideration by those engaged in the business; especially a greater freedom in parting with moisture, requiring, according to the experiments of Af Uhr, only a fractional part of the time usually allowed for spontaneous desiccation. The results appended indicate the advantage in this respect, the experiments being made on pine-wood, in a shed open at the sides, but protected from the admission of the rays of the sun and from rain. The period of the experiments was—

	From June to				
Species of Wood.	July.	August.	Sept.	Oct.	
Whole logs,.................	0·41......	0·84......	0·92......	0·98......	Per centage of original weight.
Logs deprived of bark,.........	34·53......	38·77......	39·34......	36·62......	

From these numbers it may be inferred, that by using barked wood a vast advantage is gained in point of return of capital, as the quantity of water which is evolved from the wood so prepared is only what the same quantity of timber would lose, how long soever it might be left air-drying.

Fig. 22.



Heaps of a rectangular form always afford less charcoal than the meiler process, but the loss is in some measure redeemed by the circumstance, that the operation is more easily conducted in consequence of the vents and draught-holes being more under control in this than in the conical form. The site generally chosen for the heap is a gently inclined plane, about seven to ten feet in breadth, by thirty to forty in length. Posts corresponding to the intended height of the heap are fixed vertically around this space and about two feet apart; to these boards are nailed so as to retain in its place the covering of mould or powdered charcoal, as the case may be; sometimes wicker-work is substituted for boards. The logs of wood are now placed transversely to the length of the parallelograms, taking care to have the larger ones at the base, and to fill up with lesser wood all the intermediate spaces; sometimes, however, they are arranged lengthwise. As the heap increases, the upper surface is made to present a cuneated shape, by heightening the anterior part, and gradually tapering to an angle of 15° to 20° with the horizon. When finished, the heap is no more than two feet in height at the front, whilst it increases gradually to the opposite end, where it measures from nine to fifteen feet, according to its length. A small recess is allowed in the lower extremity, as seen in the figure, for the purpose of lighting, when the arrangements have been made for that purpose, and the heap is well covered with moistened charcoal or mould, and beaten as solid as possible. Fire is placed in the chamber just mentioned, and the small wood contained in it quickly undergoes combustion; a draught is instituted by making several holes in the front of the heap, at a distance of about fifteen inches from the level of the ground. As soon as the fire takes hold on the wood of the heap, the first opening is securely closed, and others opened along the front, so as to draw the heat along the base which is being charred, whilst the upper part is undergoing the sweating stage. When a light smoke of a bluish tinge issues through any of these openings, the attendant knows that the charring conditions are favorable in those parts, and that it is time to conduct the draught to other quarters, and for this purpose the openings already made are closed, whilst others are pierced in the covering at a proper distance. After the fire has traversed the entire breadth, the draught is still maintained by making perforations in the sides of the heap near the ground, and corresponding ones in the upper surface of the mound, taking care that the current thus instituted traverses only where the wood is undergoing distillation. The practice is to draw the charcoal from that part of the heap which has been charred, as soon as the fire has extended as far forward as the heap is wide. This is continued partly throughout the operation, but so sparingly, that about half the heap will be left when the more bulky end comes to undergo active carbonization. The necessity of covering all the parts, and of sprinkling the surface of the heap with water to allay the heat in some degree, should not be overlooked. When this method is successfully conducted, the fire traverses about a foot and a half daily, causing the operation to last for a time proportionate to the length of the heap. According to Debette, the product from 35·3 cubic feet—one stère—is

In large charcoal, 27·44 cubic feet.
In small charcoal, 0·95 "

Making a total of 28·39 cubic feet, weighing about 185 pounds.

This product is much less, however, when the smaller kind of wood is employed.

The commoner and less economical methods of charring have now been noticed, but the demand for the charred article, as well as for the substances which the dry distillation of wood affords, has tended to induce a modification of the processes, with the view of enabling the charcoal-burner to obtain a larger amount of charcoal than is possible by the methods just described, and also to recover considerable quantities of the products of the decomposition of the wood.

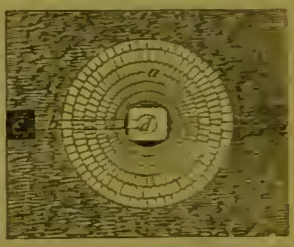
In the first of these deemed worthy of notice, the main features of the meiler are retained, but by enclosing it in sheds, which may be of wicker-work or of boards, the destruction of a portion of the wood from exposure to the wind is prevented. In the construction of this kind of covering, the advantages of its being portable and easily adjusted are obvious; hence it is generally made in divisions which are readily connected with each other, so as to form a complete shed round the pile, large enough to leave an interval of a few feet between. An opening is made at the top, for the escape of the smoke and gases, and another at the side, temporarily closed with a curtain, for the ingress and egress of the workmen. Sometimes the walls of this shed are made of solid materials, such as stone, bricks, *et cetera*, and roofed by planks or stout boards, leaving sufficient room between them for the smoke to escape. By this arrangement, the results of the carbonization are increased to twenty-two per cent. of charcoal.

Another modification of the meiler process, suggested by Brune so far back as 1801, and which was examined and reported upon by Blavier and Brochin, is said to expedite the charring, as well as to increase the yield of charcoal. The heap is in this case constructed, where the meiler is stationary, by digging a circular hole to the depth of a foot, and depositing a frame composed of bars of iron, upon which is laid a cover constructed of sheet-iron plates well riveted, and of the same area as the base of the heap. Instead of excavating the soil, an annular wall of brickwork or masonry may be built, with internal supports for the base. Care is taken to have the plates air-tight before the meiler is formed upon it; this is tested by introducing a few lighted faggots at an opening which is left at one side, and which forms a kind of hearth, and observing if any smoke issues through it. Air is admitted for supporting the combustion of these faggots through three other apertures, one of which is opposite to the hearth, and the others equidistant from it. The meiler being erected and covered, first with brushwood and foliage, and finally with moist powdered charcoal, five or six burning faggots are introduced beneath the plated base at the hearth, and the combustion is kept up with fresh quantities for about an hour, when the whole base of the meiler will be in a state of ignition. At this stage the vent-holes and the hearth are closed, and other openings made in the usual manner in the covering of the mass, closing them as combustion becomes sufficiently advanced.

The superiority of this mode is attributed to the greater conducting power of the metal than of the soil, by which the heat is distributed so rapidly as to cause the ignition of the whole of the wood in contact with it in a very short time, and without the necessity of admitting any increased volume of air. Nor is it necessary for effecting this, that the whole of the base should be heated; an area of five feet will be sufficient to communicate a decomposing temperature to a meiler of thirty feet diameter at the bottom.

Upon the same principle, although less effective in charring the wood quickly, is the plan of erecting the meiler upon a stationary foundation, so constructed as to yield a portion of the products of the distillation. Fig. 23 represents this bed vertically, and Fig. 24 its elevated section. The structure is built of bricks, and has an inclination either from the circumference to the centre, as shown in the drawings, or reversely. In the former case, the centre of the bed is hollowed perpendicularly, and from the well thus formed, an outlet leads to a brick tank at the side. The central well is represented in the drawings by *d*, the channel by *b*, and the tank by *c*. The well is covered during the carbonizing with a perforated grid to prevent its being filled with the charcoal, and care is taken not to allow the ingress of air through the channel. This method is followed for the most part in the Landes, in Pologne, and in Russia, and where resinous woods are at hand; it is designated the distillation *per descensum*, from the circumstance that the tar, resin, and such heavy products fall through the heap, and flow into the tank *c*, where they are recovered.

Fig. 23.



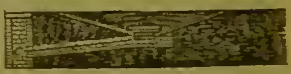


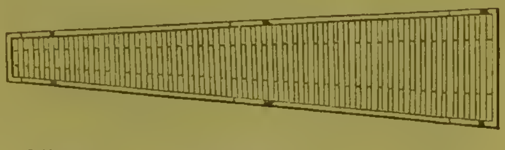
Fig. 24.

Of the various methods of carbonization which chiefly aim at obtaining the greatest amount of charcoal in the readiest way from a given weight of wood, the mode followed in America seems the most advantageous. Not, indeed, that this materially differs from the European systems, or that it does away with the necessity which is involved of consuming part of the material, but that the loss which is unavoidable is confined to matter which has less value than the charcoal. With this view, the interstices of the meiler are filled with powdered charcoal, which, by burning, gives out so much heat as to effect the rapid distillation of the wood, whilst, at the same time, it preserves the carbonized material from contact with the air. By this process it is said that about twenty-two per cent. of charcoal are obtained, which is clean to the touch, and in every respect similar to that produced by the distillation of wood in close vessels.

Such are the improvements which have been effected in operating with the ordinary meiler, having no regard to the perfection of the process by turning to profit all the products afforded by the wood; but, from the number of these, and their utility in the arts, their waste could not be long permitted, especially when their value became known. To submit the wood to distillation in close vessels, however, would involve a considerable outlay in costly apparatus, which at the same time would fail to furnish a quantity adequate to the requirements of the trades which consume it, and hence more simple, as well as more effectual methods were a desideratum. The conditions required were, to a great degree, fulfilled by the processes proposed by Foucand, Baillet, and Schwartz, but others have been suggested and acted upon.

Foucand's method, which is the simplest of these, is founded on the principle of sheds; all the other details being much the same as in the common *pile* process. A covering is provided, which, while it affords all the advantages derived by the use of sheds, adds the means of collecting the volatile products in suitable condensers; and to render it more efficient, it is so made as to be simple and economical—the diameter of the base being thirty feet, at the top ten feet, and the height eight or nine feet. To form this shed, frames twelve feet long, three broad at one end, and one foot at the other, are constructed of bars of wood two inches square. Upon these, stout twigs in the form of wicker-work are woven; wooden holders are attached to each frame, by which, and the use of an iron or wooden pin, they may be joined together. Before putting them up, it is customary to coat them with a well-tempered loam, with which some chopped grass is mixed. Fig. 25 shows one of these frames, and Fig. 26 one side with the holders appended.

Fig. 25.



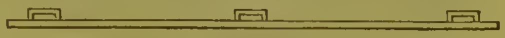
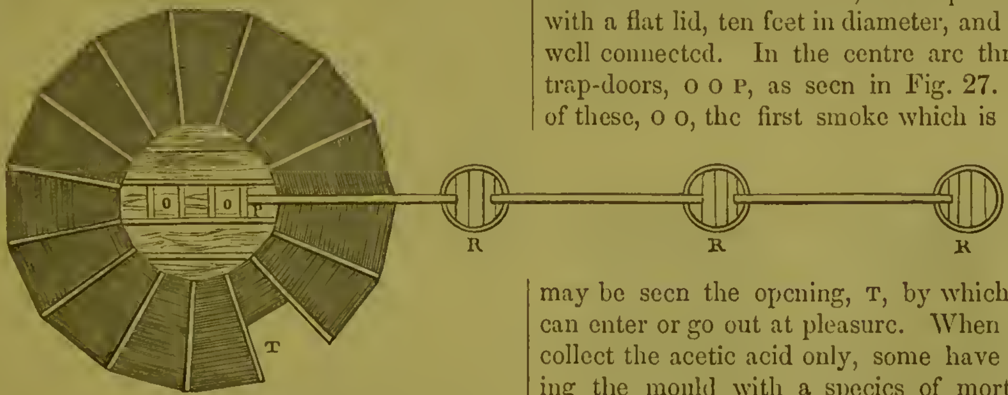


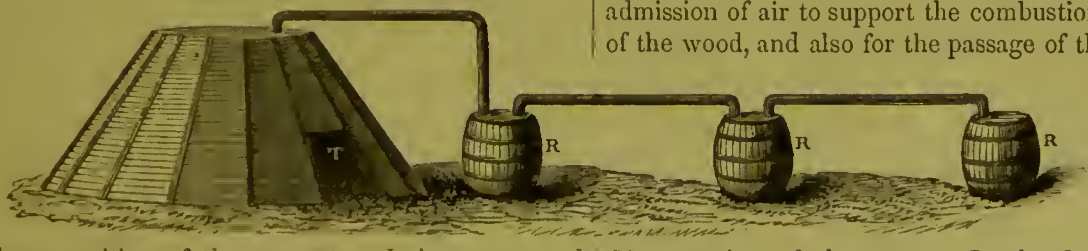
Fig. 26.

Fig. 27.



When a number of these are adjusted together, they form a frustrum of a cone, the top of which is closed with a flat lid, ten feet in diameter, and made of boards well connected. In the centre are three openings or trap-doors, O O P, as seen in Fig. 27. Through two of these, O O, the first smoke which is evolved on the meiler being ignited passes out; and after this the condensable products are drawn off through the third opening by a pipe bent at right angles, and conducted into the first of a series of condensers, R R R. This arrangement is shown in elevation in Fig. 28, where may be seen the opening, T, by which the workmen can enter or go out at pleasure. When the object is to collect the acetic acid only, some have proposed coating the mould with a species of mortar made with quicklime; the acid unites with this base, and forms acetate of lime, which may be treated as indicated under Acetic Acid.

Fig. 28.



Baillet's form of carbonizer, reproduced with various improvements in the apparatus of M. la Chabeaussière, consists of a cylindrical chamber, covered with a plate of cast-iron, and furnished with orifices, for the admission of air to support the combustion of a portion of the wood, and also for the passage of the products of the decomposition of the contents. It is constructed by digging a circular cavity in the earth of any convenient depth; or, where this cannot be done, building a mould wall round the space corresponding to the size of the furnace. When sunk in the ground, holes are made perpendicular to the base, and at a distance of a foot from the facing of the wall of the cavity; they are made to open inwards at the base. In the other form, the perforations are fixed at the base to open inwards in the same way. Fig. 29 represents this kind of carbonizer, half in plan and half in elevation, and Fig. 30 a section of the same. In the first of these, A denotes half the plan at the level of the base, and B the other elevated portion under a vertical view. The same are seen in section, where C indicates the half section over the chimney, and D the half over the air-channels.

The bottom of the furnace, E, is constructed of refractory clay, well beaten, or of bricks; so also are the side openings, G, of the air-channels in the bottom. F F indicate the mouths of these holes, H is the brick-chest or pipe for conducting the smoke, and I the casing of the same material upon which the verge of the lid rests. This most important part of the furnace is constructed of wrought-iron plates, bound by clamps or hoops of sheet-iron. Its form is a segment of a sphere, its diameter is ten feet six inches, being six inches wider than the pit, so that it will rest three inches over the edge of the wall. It ought to be sufficiently solid to bear the weight of a man without being injured. A perforation, *a*, Fig. 31, is made in the centre; this opening, which is nine inches in diameter, and closed by a movable plug of iron, serves as a vent for inducing the ignition of the wood, as well as for introducing red-hot coals for that purpose. There are four other openings, *b b*, equidistant from each other, and six inches from the rim. The diameters of these are only four inches, and they are intended as draught-holes for the escape of the first heavy vapors that are given off when combustion sets in. In diameter the furnace is about ten feet at the base, being a little more at the top, and it is nine to nine and a half feet in depth. About six inches thick of solid flooring, composed of refractory clay, is laid on the bottom, bringing this up to the level of the inlets. It should be well beaten, in order that it may the better resist the heat, as should likewise be that of the walls of the furnace. The air-holes are generally about two to two and a half inches in diameter, though openings of a less calibre would be sufficient; but by placing a tile upon the orifice, the volume of air may be reduced at pleasure.

Fig. 29.

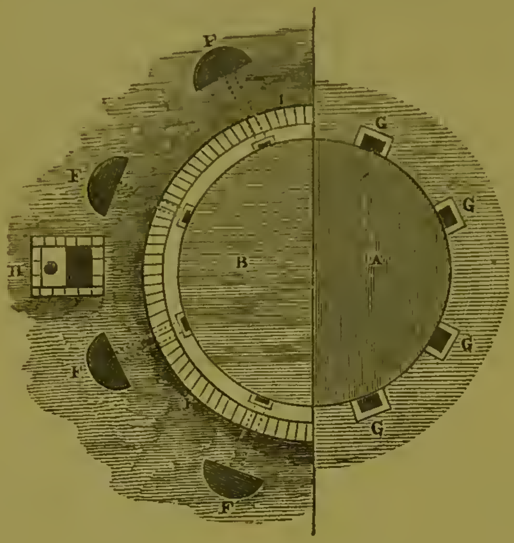


Fig. 30.

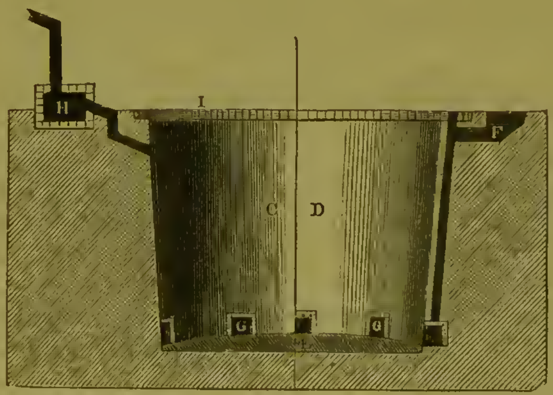
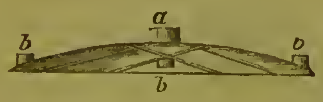


Fig. 31.



The outlet through which the volatile products pass is introduced at about nine inches below the ledge of the furnace; it is nine inches in diameter, and inclines towards the body from the further end, which abuts in a rectangular box, eighteen inches in length, twelve in breadth, and fifteen in height. During the distillation, tar and portions of the acid condense in the box, the walls of which are made of brick, the cover being a movable plate of iron; and when nearly filled, or in such a state as that it would obstruct the passage of the vapors, the excess is drawn off by a stopcock in the side near the bottom. A cast or wrought iron pipe is fixed vertically in the lid of the box, and at the height of about four feet it is bent horizontally, or slightly depressed; the horizontal part is about fifteen feet in length, so that the contents may be cooled during their passage, and prevented from spontaneously igniting. The far end of this pipe discharges itself into a wooden sluice or covered trough, which conducts the products into suitable condensers. Before putting the furnace in operation, it must be well dried by lighting some brushwood, and keeping up the heat till the bottom and sides are thoroughly baked. The charging is commenced by fixing a round stake four inches in diameter in the bottom, and of the same height as the furnace. Around this, some charcoal is placed to keep it upright, and then logs of wood are arranged horizontally, radiating towards the circumference and between the air-holes, observing that the ends reach neither to the central stake nor to the wall of the furnace. The spaces unoccupied between the radii, form so many flues from the draught-holes to the centre. Another layer of logs is laid transversely upon these spaces, and close to each other, thus leaving as few vacancies as possible. Other layers are placed upon this successively till the furnace is filled, and all the spaces round at the circumference are charged, either by alternating the logs, or by employing smaller wood for this purpose.

The next step is to withdraw the central shaft, and to fix the cap in its place; the latter operation is facilitated by the use of two iron levers and wooden rollers twelve feet in length, which pass over the furnace and rest on the ground at each end. All the openings in this cover are left free, and the remainder is coated with a layer of loose dry earth or sand, two inches thick, in order to cause it to be as retentive of the heat as possible. The draught-holes round the circular wall of the furnace are likewise opened. At this stage, some red-hot embers are poured down the central vent-hole through a kind of funnel, and these falling through the space previously occupied by the stake, which acts as a kind of chimney, come in contact with the combustible material at the bottom, which is soon ignited. For the purpose of diffusing the flame over the contents of the furnace, the central orifice is closed as soon as the fire has acquired sufficient strength. After the bluish smoke which escapes from the charcoal changes to a whitish shade, the draught-holes in the cover are partly closed, as are also those leading to the base of the furnace; and when the combustion is thought sufficiently brisk, the openings in the cover are entirely stopped, and the vapors allowed to pass off to the condenser. Sometimes the draught produced by the chimney at the end of the condenser is not powerful enough to cause a rapid transmission of the gases and other volatile products from the furnace, in which case the fire is apt to flag or become extinguished. This state of things is detected by the vapors being driven back in the outlets through which they ought to proceed. To remedy the evil, the air-holes at the top of the cover might be opened and a portion of the products allowed to escape, rather than suffer the fire to go out; but the best contrivance is to have a second opening at the top of the furnace, to which pipes may be appended for conducting the gases off to the condenser, but capable of being closed when not required.

The charring generally requires from sixty to eighty hours to produce a good quality of charcoal, but the period is, of course, variable. The attendant examines the state of the interior by thrusting a pole into the furnace through the central opening, and observing if the reduction in the bulk of the mass be equal in all parts. If this be not the case, the draught-hole is opened near that part where the subsidence is least, as also the air-hole opposite to it at the base, and in a very short time the equilibrium is re-established. As soon as the charring is thought to be completed, either by examination with the pole or from the appearance of the smoke which may be evolved, all the air-channels and draught-holes in the cover are opened, with the exception of the central one; a brisker combustion ensues, and some hydrogen which has been hitherto retained is given off. In consequence of this, the charcoal changes from a reddish-brown to a black color, and is so far rendered more marketable. Immediately on the surface of the charcoal becoming incandescent—a state which may be observed by looking through the orifices in the cover—all the openings by which air entered or vapors escaped are carefully closed; the temporary covering on the cap is removed, and replaced by a coating of thin loam. Thus secured, the whole is left from seventy to eighty hours to cool. The furnace is then uncovered for the purpose of removing the charge of charcoal.

It will be observed that the contents at this period possess no more than half the bulk of the wood originally introduced; this reduction arises not from the actual contraction of the matter in charring to that extent, but from the filling up of the interstices by the burned material.

A workman now descends into the furnace and empties it of its charcoal, by taking the pieces up one by one, using as much precaution as possible that they are not broken. The smaller fragments and charcoal dust are removed with a shovel, and collected in a heap together. Should the contents not be thoroughly cooled, the workman employs an iron tool which protects his hands from the heat. Any live or half-burned charcoal which may be present is assorted by itself, then spread out and occasionally raked about, by which it becomes extinguished of its own accord, and without the use of water; it would be well, however, to have some at hand, in which to immerse any pieces that may be detected burning, which is known by the appearance of white spots. When the furnace is emptied, it is re-charged in the manner already described, and all the operations are repeated in the same manner, and proceeded with as previously detailed.

Five active workmen have been found sufficient to superintend successfully eight such furnaces, working without interruption, and producing on an average twenty per cent. of charcoal throughout the year. The following statement of the work of these furnaces gives a fair average of their annual produce :—

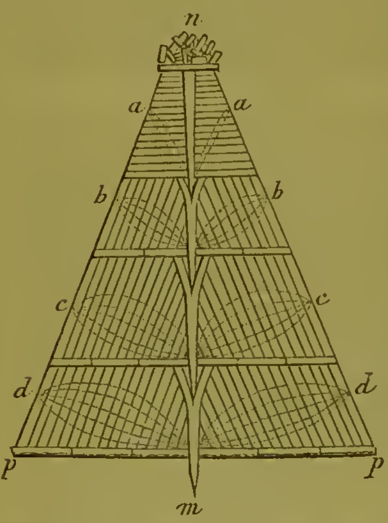
	Tons.	Cwts.	Qrs.	Lbs.	
5000 stères of oak, weighing	123	0	3	16	produced
16,000 hectolitres of charcoal, weighing..........	24	12	0	21	
Impure acetic acid,........	22	0	0	17	
Yielding upon distillation a purified article, marking 12° Twaddell, weighing from	12	15	3	21	
To	13	15	2	14	

The outlay in the construction of each furnace is said to be four hundred and fifty francs, or about eighteen pounds fifteen shillings, of which sum sixteen pounds thirteen shillings are paid for the cap, the balance being ample for constructing the body of the furnace. The condensing apparatus is not included in this statement.

On reference to the article ACETIC ACID, Vol. I. p. 18, the apparatus of SCHWARTZ will be found fully described; and, therefore, any further description of it will be here unnecessary; but something may be added as to its efficiency compared with the others. In localities where there is considerable demand for charcoal, such as in some parts of France and Sweden, where it is largely consumed in smelting operations, the apparatus of SCHWARTZ is better adapted to yield the requisite supply than LA CHABEAUSSIÈRE'S; it likewise answers better for coniferous woods, as the large amount of tar which these yield is most effectually recovered by it. On the other hand, it must be admitted that the wood is more completely charred in the latter, and the time occupied in proportion to the bulk is much shorter; that the cost of SCHWARTZ'S apparatus is much greater, and that it does not admit of removal like LA CHABEAUSSIÈRE'S, except under an outlay as great as the original cost of erection, namely, from eighty to ninety pounds. The advantage of using either of these forms depends greatly upon the facility with which the wood may be conveyed to the meiler, as it is evident that, if the distance were great, the cost and difficulties of the carriage of wood over that of the charcoal would more than balance the value of the products of the distillation, and, in fact, of the greater yield of charcoal. In this case, the first method of carbonizing, in large meilers, enclosed in easily movable sheds, will claim a preference to the other two; but sometimes, when the piles are required to be very large, the removal of these becomes more difficult and troublesome; so that their advantages are considered inadequate to the labor, and they are consequently dispensed with. It is evident, therefore, as DUMAS remarks, that in such districts all the improvements to be made in the manufacture of charcoal must turn upon the better working of the meiler or pile, as being the most applicable; and hence, the first thing to be aimed at is to render this more independent of the cares of the workmen. Upon this, the difference between the pile system and that of distilling in close vessels turns; for, by the former, the most skilful practitioner may be baffled by circumstances peculiar to the operation; whilst, in the latter, the smallest amount of hand labor will always serve to prepare the charcoal, and in the largest quantity.

It is clear that the first consideration on the part of the burner of the pile is the lighting of the fire, so as to spread it over the largest extent of surface in the shortest possible time, and with the admission of as little air as possible. This is usually done by igniting the mass at the base, establishing a draught at the same time from the exterior and through the centre, as seen in Fig. 32, at *p m a*, till the upper parts of the pile are on the point of entering into incandescence. By closing the chimney, *n*, and opening vents at the points, *a a*, around the mound, a draught will be formed through *p m a*. These perforations will in turn be closed, and new ones opened in succession; and as the carbonization advances in *b c* and *d*, care must be taken to bring the force of the combustion in the direction of *p m b*, *p m c*, *et cetera*, so as to char the whole in zones proceeding from the axis to the circumference, and then downwards towards the base. Such is the course which is deemed the most favorable for the charring; but it is evident that this does not include all that is deserving of the operator's attention. An object, indeed, of primary consideration, is to render as much as possible of the caloric disengaged in the process available for decomposing the molecular arrangement of the matter of the wood. Could this end be fully attained, it is evident that the whole of the carbonaceous matter might be obtained in the form of charcoal. How far this is from being accomplished in the meiler system, those engaged in the business are best aware; as likewise how great a loss the slightest variation of temperature inflicts upon them. This regulation of the heat is, however, a problem, the solution of which would involve the removal of serious difficulties—a fact which will be readily admitted when the amount of water to be discharged as steam, the volume of gases liberated, and of air passing through the pile, are considered.

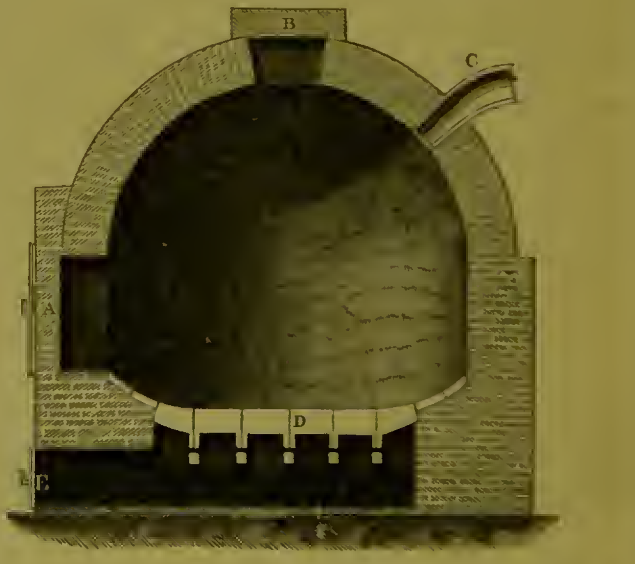
Fig. 32.



A method adopted in Sweden, which seems to be an improvement on the common plan, is to conduct the draught downwards instead of in the ordinary way; and if the pile were constructed upon a base sloped from the centre to the exterior, this would allow of the draining of the tar, acetic acid, water, *et cetera*, into a suitable vessel. Pipes might be disposed through it, so as to conduct the draught from the vertex to the base of the cone, and all converging into a tank, where the vapors would be condensed as far as possible, the remainder passing out through a flue into a chimney of sufficient height to generate a draught powerful enough to carry on the combustion. By this course all the heat would be utilized, and the moisture disengaged would be prevented from passing through the ignited wood—a circumstance which causes considerable reduction of the charcoal left.

Another species of charring is that in which the heat is exterior to the wood which is to be carbonized, and is produced in an adjoining fire. Of this description of carbonizers is that represented in Fig. 33, a construction of brickwork, having apertures suited to the convenience of the workmen for charging and withdrawing the products. Of these, A shows the orifice through which the wood is introduced till it rises as high as this opening, after which it is closed, and the remainder of the interior charged through the superior aperture. B, and the orifice for the passage of the products of distillation is through the pipe, C. The fire which serves to bring the contents to the point of decomposition is made on the grate, D, and the air which is to maintain its combustion enters by the ashpit, and is regulated by a door, E. When the kiln is charged, the apertures, A and B, are blocked up with bricks, or closely fitting lids. As soon as the walls have acquired so much heat as will be necessary to complete the charring, the communication with the air is cut off by closing the door, E. In carbonizing in this manner, the charring is more regularly effected, although the supervision of the attendant cannot be so well exerted as when the ordinary meiler is resorted to; in the latter, however, the influence of the weather can scarcely be controlled, however watchful the workman may be—a condition effected by the walls of the kiln, and hence its superiority.

Fig. 33.

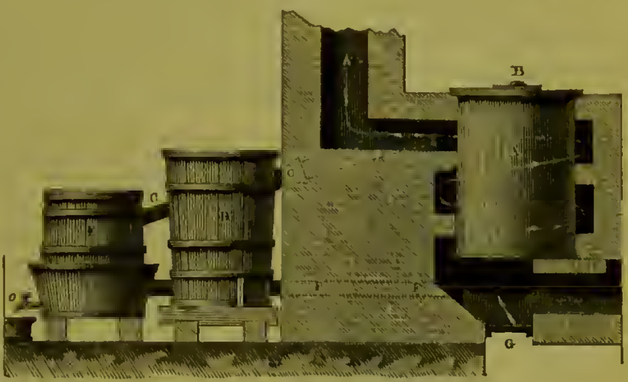


Differing from the kilns of this description, but still less advantageous in point of execution, are those kinds of carbonizers which char the wood without allowing the products of the combustion to come into contact with the materials to be decomposed. They possess an advantage over others, inasmuch as all the volatile products are recovered in the condenser, without anything being lost from a combustion taking place in contact with them. This advantage is partly neutralized by the large amount of fuel which is required to bring their contents to the proper working temperature, and the necessarily small volume which must be operated upon, owing to the non-conducting qualities of wood and charcoal. No less than a quarter of the product in charcoal is consumed for this purpose, even when the combustible gases which pass through the condenser unarrested are economised in the grate.

The close distillatory apparatus or retorts are the most eligible for the decomposition of pine wood, and such as contain a large amount of resins; and though, at a distance from the site where the wood is felled, they are generally composed of iron, yet near the locality they are sometimes constructed of well-tempered clay. Those known as tar-retorts are composed of two hollow cylinders, one within the other, and differing six or eight inches in diameter. The inner of these receives the wood, and is a little longer than the outer one. The space between them is appropriated to the fire, which is maintained by a current of air rushing in through apertures in the outer walls. A funnel shape is given to the base of the retort, and this is made to terminate in a pipe which traverses the outer cylinder, and abuts in a tar cistern where the products of distillation collect. By means of an aperture at the top of the inner cylinder the wood is introduced, and after the charging is performed, and all the outlets closed with the exception of those at the base, the fire is lighted in the intervening space between the outer cylinder and the retort, and the heat continued as long as volatile matters pass over to the receiver. When these cease, or sooner, provided the walls are sufficiently hot to finish the distillation, the fire is extinguished, and the apparatus allowed to cool.

A very good form of retort for the distillation of wood and the production of tar and charcoal, is that shown in Fig. 34 annexed. The body, A, of the retort is of cast-iron, imbedded in masonry or brickwork, so that the flue from the grate courses spirally to the top, where it turns off to the chimney. In the upper part of this case is a movable cover, B, through which the wood is introduced, and by which the charcoal is removed when the charring is finished. An outlet is made at the top under the rim, to which a pipe, C, is fixed that communicates with a large condensing vessel, D, covered at the top; this is connected with another, E, wherein all the condensable matters which escape from the first are arrested and conducted to a recipient by the pipe and stopcock, *o*, whilst the non-condensable gases are reconducted by a pipe, F F, over the grate of the furnace, G, to be burned, and thus economise the fuel. The fire is made of faggots and brushwood, and is maintained till gases and vapors are abundantly evolved, at which stage a stopcock in the pipe, F F, is opened, and the inflammable products of the distillation are allowed to flow in over the fire, where, in burning, they produce as much heat, with a little addition of fuel, as will char the remainder of the contents. After the condensable matters cease to flow over, this tap is shut, and the retort is left to cool for a period of sixteen to twenty hours.

Fig. 34



Such are the principal methods resorted to for the manufacture of charcoal from wood for the requirements of the smelter, the powder-maker, and others. It is evident, from the nature of the several processes, that considerable difference must necessarily exist between the charcoals produced, as well in their intrinsic value as in their physical appearance. This partly depends on the species of wood employed; but all the difference is not to be attributed to this circumstance. The study of charcoal, with a view to its application in the works where it is chiefly consumed on the Continent, has led to a modification of the usual mode of charring, by which a larger volumetric yield has been insured, answering all the purposes required. This product is designated *torrefied wood*, or *red charcoal*, from its reddish-brown appearance. Berthier was the first to call attention to this variety; but lately Sauvage conducted some experiments, from which he deduces that the amount of combustible matter obtained by the charring of wood does not increase after exposing the material to a suitable heat during a stated period, but that, on the contrary, a loss is sustained in the quantity. He limits the proper period to five hours and a half. The results of his experiments are transcribed in the annexed table, which shows the loss sustained in weight, and the volume at the intervals mentioned:—

100 lbs. Wood charred for	3 hours.	4 hours	5 hours.	5·5 hours.	6·5 hours.	Mound Charcoal.
Weighed	65·4 pounds.	53 pounds.	47 pounds.	41·5 pounds.	39·1 pounds.	17·2 pounds.
100 cubic feet by a similar treatment measured	86 C.F.	76 C.F.	58 C.F.	55 C.F.	52 C.F.	33 C.F.

When the following numbers are considered in connection with the preceding table, the loss sustained in combustible matter will become apparent:—

AMOUNT OF COMBUSTIBLE MATTER CONTAINED IN

1 cubic foot of wood,	968	parts by weight.
1 " " charred during 3 hours,	883	" "
1 " " " 4 "	904	" "
1 " " " 5 "	1133	" "
1 " " " 5·5 "	1091	" "
1 " " " 6·5 "	1136	" "
1 " meiler charcoal,	1096	" "

The usual method followed in France and Belgium for manufacturing charcoal, is by a kind of meiler or pile lengthened out, and having a channel cut in the floor, as shown in transverse section in Fig. 35, and longitudinally in Fig. 36, both in elevation. The fire is made at B, and the warm gases are forced along the channel, A, by the fan, C; these products of combustion spread through the heap, and heat the wood to the point of carbonization. Generally, the management of the pile is the same as when working in the ordinary way. Much difficulty is experienced in properly conducting the process to produce satisfactory results; and frequently it happens that nothing but *black* charcoal remains. In the department of the Ardennes, where smelting is carried on, the waste heat from the furnaces is economized by making it carbonize the wood and convert it into red charcoal. The course adopted is to place the material in cylinders, conducting the heated gases of the furnace through them for a certain period. By the heat thus communicated, the wood is made to sustain a loss varying from thirty to fifty per cent. When only thirty per cent. is lost, the substance is merely dried, and the heat must be prolonged till the charring has reached to the proper limits, discerned by the color and weight of the body. It would appear that although there is generally an advantage in treating the wood thus, yet the red charcoal is very seldom homogeneous in composition. In this respect, the best results hitherto arrived at are those of VIOLETTE, who employed high pressure steam, having a temperature of about 572°.

Fig. 35.

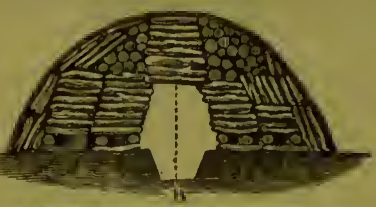
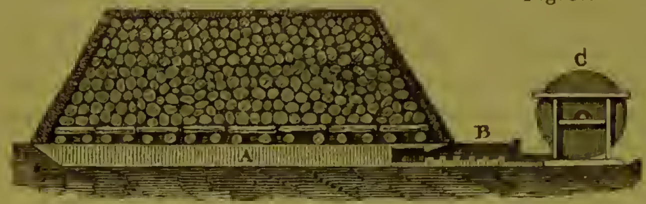


Fig. 36.



Charcoal, in whatever way it is prepared, is dependent for its quality, as well as for the quantity, first upon the wood, and secondly upon the course of operations to which the latter is subjected. As to the former, the details already given of the composition of the different kinds, will be sufficient to show, that the amount of carbon in a given weight or volume is greater in some species than in others, and, consequently, these will yield a product containing more combustible matter for the same bulk than lighter woods. It is difficult, however, to make experiments decisive of the relative value of the various systems of charring in relation to the yield in carbon, or the relative loss of carbonaceous matter which woods sustain while undergoing decomposition by heat. Indeed, it may be said that most of the results of the investigations hitherto undertaken afford only approximations to the truth. The most accurate, perhaps, are those obtained by JUNCKER, who endeavored to determine the yield of charcoal from samples of different kinds of wood, all about thirty-two years old. The woods were weighed and charred in heaps of equal size, using all possible diligence in the operation; and as soon as the charring was finished, and the product cooled, it was weighed immediately, and before moisture could be absorbed. The weights taken afforded the annexed results:—

	Centesimally.	
	Charcoal	Half-charred wood
Green red beech, cut in May, 1832,	19·7 ..	0·6
" " " " without bark,	23·0 ..	0·3
Dry red beech and oak, two years old,	24·0 ..	0·3
Dry oak, two years old, and without bark,	25·7 ..	0·34
Green oak, cut in May, 1832,	22·4 ..	0·3
" " " without bark,	21·2 ..	—
" " " with bark	18·8 ..	1·0
Equal parts of barkless red beech and oak, cut in Jan., 1831, and carbonized in Aug., 1831...	23·4 ..	0·5
Green red beech with bark, charred immediately,	12·9 ..	0·3
Green oak immediately charred,	13·5 ..	0·4

The first five experiments were made in August, a season most favorable to the charring, and the others in January, a time less propitious; but when it is considered that the amount of water in the woods at the period of carbonization was left undetermined, and that this exercises a powerful action upon the charred substance, diminishing considerably the product, it is evident, from what has been previously said, that something is wanting to render the results conclusive.

Researches of a similar nature undertaken at Eisleben, where the operation of charring was effected in piles thirty feet in diameter, afforded the subjoined numbers:—

	Centesimally.	
	I.	II
From Oak-wood in split logs,	21·3 ..	23·4
" Red beech,	22·7	
" Birch,	20·9	
" Beech,	20·6	
" Pine,	25·0	

Other experiments with the same object have given, by the meiler process, results varying from twenty to twenty-eight per cent., and averaging twenty-three per cent. of the wood taken, whilst the produce of the kilns in the same quarters has been shown to be only a mean of about twenty-six per cent.; and this, when the quantity consumed in the operation is deducted, leaves only about twenty-two per cent., or rather less than that afforded by the ordinary process. It must be remarked, however, that the meiler yield was in these cases an exception to their general produce, which is found much lower than the numbers so given, even when thick wood is operated upon; and the proportion is much further decreased when small wood is charred in them. It is a well-known fact, however, that none of the methods give, in the form of charcoal, more than two-fifths of the real amount of carbon in the dry wood. According to EBELMEN, this loss is occasioned not entirely by the products of the distillation carrying off portions of it in combination, but by the direct combustion of the charcoal in an incandescent state, caused incidentally by the oxygen of the air passing through it, and converting it into carbonic acid and carbonic oxide. This he proved by the comparative analysis of the vapors from the temporary chimneys in the meiler, and of those developed in close vessels, where contact of the fire was entirely excluded. Of course, if the portion of carbonic acid which must necessarily be generated is permitted to traverse the incandescent charcoal, it will suffer decomposition at that temperature, and as much more carbon as it contained will be assimilated and lost to the charcoal-maker, the whole passing off in the form of carbonic oxide. The charcoal-burner's efforts should be directed to prevent this, by conducting the air which enters the meiler over the uncarbonized wood; and after it passes that part of the heap where combustion is active, withdrawing it by means of the temporary openings in the cover, over the portion yet undecomposed, so as to be out of the reach of the made charcoal. It is almost impossible to effect this thoroughly, but the efforts made with that view by those engaged in the business show that its importance is appreciated, and doubtless a remedy will soon be found which will render the process more effectual than it is at present.

QUALITY OF THE CHARCOAL.—A few considerations may now be submitted with reference to the quality of the charcoal. Independently of the fact of the densest being the best, it happens that during the making it may be deteriorated, either by imperfect charring, or by pushing the process beyond the proper limits. In the former case the product is not good, on account of the gaseous elements which it retains, and which being disengaged in its subsequent application as fuel, render it less efficient for producing a high temperature; in the latter case it becomes so brittle as to be incapable of being handled without falling to powder: and the same crumbling occurs in the smelting furnace, where it is more injurious.

Good charcoal is very dark, possesses a bright lustre and somewhat conchoidal fracture; it resists gradual pressure to a considerable extent, and produces a sharp sonorous sound when allowed to fall upon a hard body. It should burn when ignited without either flame or smoke, and when handled no stain ought to remain. Although in bulk it floats in water, owing to the arrangement of the particles, its specific gravity, when ground so as to destroy its porosity, is much higher than that of water. In addition to the carbon of which it chiefly consists, a certain amount of oxygen, hydrogen, and other gases is found in it, together with the mineral matter of the wood. The greater or less proportion of the former affects its calorific power, and renders it more or less eligible for certain uses in the arts.

The following analyses of two samples of charcoal prepared by the meiler system, show the quantity of the different ingredients remaining, even after the charring has been carried to its utmost limits:—

	Centesimally represented.	
	Charcoal from Young Oak.	Charcoal from the Aspen.
Carbon,	87·68	87·22
Hydrogen,	2·83	3·20
Oxygen,	6·43	8·72
Ash,	3·06	0·86
	100·00	100·00
Loss by distillation,	13·02	17·07

Red charcoal retains a somewhat larger quantity of the above gases, than the product of the meiler or the close retort. The following table embodies the results of M. VIOLETTE's analyses of the charcoal prepared by the action of superheated steam, according to his process:—

Species of Charcoal.	Elementary Constitution Centesimally Represented.			
	Carbon.	Hydrogen.	Oxygen, Nitrogen, and Loss	Ash.
Furze,	76·629	4·108	17·975	1·288
Iron wood,	72·564	4·527	12·510	0·399
Cork,	72·362	8·528	19·110	..
Juniper,	71·433	5·073	23·324	0·170
Wild pine-tree,	71·358	5·948	22·194	0·500
Hawthorn,	70·793	4·443	23·419	1·345
Palm-tree,	70·724	4·552	23·494	1·230
Ash,	70·395	4·539	24·374	0·692
Maple,	70·069	4·613	24·892	0·425
Cherry-tree,	70·028	3·928	25·289	0·755
Lime-tree,	69·829	5·452	23·024	1·695
Yew,	69·620	5·864	24·212	0·304
Sycamore—maple,	69·229	4·402	25·133	1·236
Medlar,	69·209	4·643	25·261	0·887
Chestnut-tree,	69·127	4·326	27·126	0·421
Willow,	68·900	5·133	24·634	1·333
Yoke-elm,	68·835	4·142	26·382	0·641
Poplar—trunk,	68·741	4·866	25·540	0·853
Coco-tree,	68·268	4·053	23·984	3·695
Hollyoak,	68·521	4·741	25·891	0·847
Aspen,	68·169	5·512	25·730	0·589
Ebony,	68·047	3·868	28·380	0·205
Oak,	67·421	4·099	28·480	0·200
Poplar—root,	67·020	5·217	26·675	1·088
Elm,	66·862	4 669	28·181	0·288
Plum-tree,	66·118	5·756	27·530	0·596
Pear-tree,	65·924	5·310	28·244	0·522
Hemp-stalks,	62·127	4·976	31·501	1·396
Wheat-straw,	61·090	4·365	34·786	0·759
Leaves—poplar-tree,	52·514	4·819	41·289	1·388

In this table considerable difference in the yield of carbon is apparent; but as the samples were prepared by the application of the same temperature, it is evident that the inequality must be owing to a difference in the principles contained in them, and to the greater or less difficulty with which they are decomposed. It must be remembered, however, that the woods themselves do not contain the same amount of carbon. Were the water and ligneous matter the same in all, probably the approximation of the results of analysis would be closer. The quantity of inorganic salts in the various samples is very small, much less so than one might suppose, considering that wood containing about twenty per cent. of moisture gives from one-third to one per cent., all of which is retained in the charcoal produced from it, generally amounting to about twenty per cent. The following results obtained by WINKLER are, therefore, more in accordance with what might be expected:—

	Ash Centesimally.
Lime-wood charcoal,	3·55
Maple,	2·27
Ash,	2·27
Elm,	2·17
Willow,	1·50
Fir,	1·44
Pine,	1·38
Poplar,	1·30
Beech,	1·25
Scotch fir-wood,	1·11
Birch,	0·80
Oak,	0·75

Many varieties afford as much as five and even ten per cent. more, especially if the wood has been grown upon silicious soils.

A remarkable property of charcoal is, that it absorbs with avidity gases and vapors, condensing them within its pores to a most surprising extent, as shown in Vol. I., p. 764. In consequence of this property, it cannot be exposed to moist air for any length of time, without exerting a hygroscopic action, and assimilating a variable per centage of water, in proportion to the time of exposure and the humidity of the atmosphere. From experiments made with freshly prepared charcoal, NAU obtained the subjoined numbers after exposing the samples twenty-four hours to an atmosphere loaded with moisture:—

	Amount of water absorbed in twenty-four hours. Centesimally represented.
White beech charcoal,	0·80
Ash,	4·06
Oak,	4·28
Birch,	4·40
Larch,	4·50
Maple,	4·80
Pine,	5·14
Red beech charcoal,	5·30
Horse-chestnut,	6·06
Elm,	6·60
Alder,	7·93
Scotch fir,	8·20
Willow,	8·20
Italian poplar,	8·50
Fir,	8·90
Black poplar,	16·30

This proportion slowly increases when the exposure is prolonged, as proved by WERLISCH, who found that one hundred parts of charcoal, weighed on the 24th of June, became—

On the 30th of June,	104·35
„ 7th of July,	105·63
„ 16th „	106·57
„ 29th „	107·62
„ 20th of August,	108·16
„ 17th of September,	108·44

These numbers do not indicate, however, the actual amount of contained moisture, as the charcoal had not been taken immediately from the meiler, so that it might have already absorbed from three to four parts of water, as the former table shows.

The lower the temperature at which the carbonization has been effected, the proportion of water is greater. The results of VIOLETTE's experiments on this subject are given below. The samples, consisting of charcoal from black alder, prepared at increasing temperatures, were exposed in a room, the air of which was saturated with moisture, and the amount of absorption determined every eight days, no number being taken till the results of two successive trials agreed:—

Temperature of carbonization. Deg. Fahr.	Quantity of water absorbed by 100 of charcoal	Temperature of carbonization Deg. Fahr.	Quantity of water absorbed by 100 of charcoal.
302	20·862	554	6·929
320	18·220	572	7·608
338	18·180	590	7·290
356	16·660	608	5·554
374	11·626	626	4·544
392	10·018	644	5·904
410	9·742	662	5·834
428	8·954	810	4·704
446	8·800	1873	4·676
464	6·666	2012	4·444
482	7·406	2232	4·760
500	6·836	2372	2·224
518	6 306	2732	2·204
536	7·879		

To account for the very high numbers with which the table commences, it is to be observed that the product resulting from the low degrees of temperature was not more than half-burned charcoal, hence its proportionally greater hygroscopic power.

The density of charcoal depends chiefly on that of the wood; hence it is evident that the relative weight of the wood will afford a good idea of the nature of the charcoal produced from it. This fact is of much importance, as the value of the material for fuel may, to a considerable extent, be deduced from its specific gravity. The value of this, for several species of wood, as determined by HASSENFRATZ, is as follows:—

	Specific gravity.
Birch wood charcoal,	0·203
Ash,	0·200
Wild service wood,	0·196
Red beech,	0·187
White beech,	0·183
Elm,	0·180
Red fir,	0·176
Maple,	0·164
Oak,	0·155
Pear,	0·152
Alder,	0·134
Lime,	0·106

These numbers, however, merely indicate the weight of various samples when the interstices have been filled with air, and, therefore, do not represent the true gravity. In the appended table, the real specific gravity as determined by VIOLETTE is given. The course which the latter adopted was to immerse the sample, already weighed in air, in a flask three-quarters full of distilled water, allowing it to remain exposed to light for eight or ten days; by filling the flask at the end of this period to the usual mark, and then determining the total weight, and from this deducting that of the flask and liquid, the difference by the usual formula gave the specific gravity:—

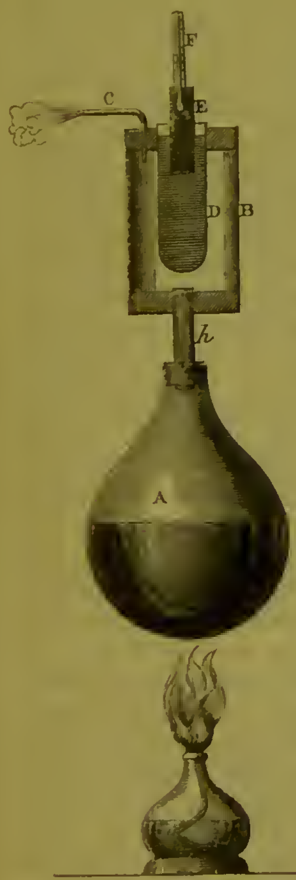
DENSITY OF THE CHARCOAL OF BLACK ALDER PREPARED AT INCREASING TEMPERATURES.

Heat of carbonization. Deg Fahr.	Density of charcoal
302	1·507
338	1·490
374	1·470
410	1·457
446	1·416
482	1·413
518	1·402
554	1·406
590	1·422
626	1·428
662	1·500
810	1·709
1873	1·841
2282	1·862
2732	1 869
fusing point of the retort,	2·002

The density in this case is therefore greater than that of water, but still it varies to a certain extent with the temperature at which the substance has been prepared; thus the charcoal obtained between the temperatures 302° and 518° Fahr. decreases in density from 1·507 to 1·402; while, on the contrary, that which is afforded between 518° and 662° increases from 1·402 to 1·500; and from this point the density continues to increase, till, at the fusing point of the vessel, it becomes double that of water.

Before proceeding to the other materials which constitute fuel, a few observations may be made on the power of charcoal to conduct heat, and the facility with which it undergoes combustion.

Fig. 37.



It is a well-known fact that the product resulting from a high temperature, or in other words, black charcoal, is a much better conductor of caloric than that formed under the influence of a lower heat; it requires also a higher temperature to ignite it; but when this is effected, and an adequate supply of oxygen is kept up, the combustion proceeds steadily, and the heat given off is regular and sustained. Considerable difficulty is found in making accurate determinations of the conducting power of charcoal. The ingenious method of M. Violette deserves particular notice, as it affords in a simple manner the conducting power of this substance, and may, by a slight adaptation, be rendered available for determining questions of importance concerning the philosophy of heat in bodies.

Fig. 37 shows the arrangement of the apparatus, in which A represents a glass flask half filled with water and heated by a lamp; this is connected with another glass cylinder, B, closed by tightly fitting bungs, by means of a glass tube, *h*. In the superior cork or cap of the tube, B, is an opening which receives a third tube, D, nearly filled with mercury, in which is immersed the sample of charcoal, the conducting power of which is to be determined. This is seen in the figure at E, and in its upper end there is made a perforation for the reception of a small mercurial thermometer, F, for the purpose of registering the rays of caloric conducted by it. The entire length of the sample, in the experiments made by the inventor of the apparatus, was 0·984 of an inch, of which 0·236 of an inch was immersed in the mercury; 0·195 of an inch of the sample intervened between the latter and the bulb of the thermometer. The source of the heat was the steam circulating in the vessel, B, and escaping through the outlet, C. A portion of the caloric of the vapor was abstracted by the mercury, so that it was retained at about 204·8° Fahr. The numbers given in the annexed table were obtained by noting the register of the thermometer at intervals of five minutes till the indication remained stationary: this happened after fifteen minutes' immersion. By employing a bar of iron of the same dimensions as that of the charcoal, and introducing the bulb of the thermometer in a like manner, a comparison was instituted between the charcoal and this substance of known power of conduction.

CONDUCTING POWER OF CHARCOAL OF THE SAME WOOD—BLACK ALDER—PREPARED AT INCREASING TEMPERATURES:—

Temperature.		Indication of the Thermometer.			Conducting power of Charcoal compared with that of Iron represented by 100.
Of the carbonization.		After 5 minutes.	After 10 minutes.	After 15 minutes	
316° Fahr.	27·00	56·00	57·0	57°5	59·5
392 "	27·00	57·00	57·5	58·0	60·1
482 "	27·00	57·50	57·5	58 0	60·1
572 "	27·00	58·00	59·0	59·5	61·6
1873 "	26·50	61·00	62·0	62·0	64·2
2282 "	26·50	62·00	62·50	63·0	65·2
2732 "	26 00	63·00	63·5	64·0	66·3
Charcoal of gas retorts.	26·00	81·00	82·0	82·0	84·7
	22·00	96·50	96·5	96·5	100·0

The numbers in the last column were obtained by multiplying those of the preceding one by 1·036. Between the temperatures 572° and 752° the conducting power is low, and is nearly the same in the wood and the charcoal produced from it; but when the heat is elevated, the density of the charcoal increases rapidly, till it is about two-thirds that of iron.

Regarding the combustion of charcoal, it will be observed, upon taking pieces of it, produced by different modes of working or by unequal degrees of heat—plunging one end of each in the flame of alcohol till ignited, and then allowing it to rest in tranquil air—that very different phenomena will be exhibited in the combustion. The charcoal made at low temperatures, say between 302° and 482° Fahr., burns with a long yellow flame, disengaging large volumes of smoke, and retaining the temperature of combustion for about fifteen minutes, at the end of which time the cylinder will have burned about half an inch. On the other hand, if the wood has been submitted during carbonization to a heat between 482° and 809°, the combustion of the charcoal under the same circumstances is characterized by a clearer flame, which is less fuliginous and persistent, and by being continued for a longer time, more especially with those samples prepared between 482° and 662°. The charcoal prepared at 809° does not burn so well as any of the samples obtained at a lower heat, nor does the ignition continue so long. When the carbonization is effected at the higher degrees represented in the foregoing table, the cylinder of charcoal, on being introduced into the flame, becomes red-hot like a bar of metal, affording no flame, and is extinguished immediately on withdrawing it, without giving any indication of combustion or leaving a coating of ash. In this last case, the fingers are unable to hold the cylinder whilst its end is in the flame for any length of time, in consequence of the freedom with which it conducts the heat.

All the preceding samples, when reduced to powder, present the same phenomena with respect to combustion as when in solid pieces, only with greater intensity, because, on account of the air interposed, the ignition is easily propagated and maintained. When, however, the experiment is conducted in a very tranquil atmosphere, the burning ceases after a part is consumed. This effect must doubtless be owing to the carbonic acid, which, being heavier than common air, does not ascend with sufficient freedom to permit the oxygen of the latter to come in contact with the burning matter.

In many manufactories where this article is required in powder, great care must be exercised, as it often happens that spontaneous combustion takes place. The most inflammable charcoals take fire at 572°, and those that are prepared at the latter heat invariably ignite at a temperature varying from 680° to 716°, according to the nature of the wood. Charcoal, from light and porous woods, always burns more freely than that obtained from the hard and dense kinds; but even the same wood furnishes charcoal that ignites with greater or less facility according to the temperature at which it has been prepared, as may be seen from the following table:—

TABLE SHOWING THE TEMPERATURE AT WHICH THE CHARCOAL, FROM THE SAME WOOD, PREPARED AT INCREASING TEMPERATURES, BURNS.

Charring temperature.	Temperature at which the charcoal takes fire.	Charring temperature.	Temperature at which the charcoal takes fire.
500°	644	1873 2282 2372 2732	1122 to 1472
518 536	644 to 680		
554 572 590 608 626 644 662	680 to 698		
8093	752	Charcoal prepared at the point of the fusion of the cylinder,	2282

Other particulars concerning charcoal, so far as relates to the manufacture of gunpowder, will be introduced under that head.

PEAT.—Another article of fuel, much employed for domestic purposes, as well as for many manufactures, in which it has lately found admittance, is *Peat*. Such is the name by which the brownish-black spongy substance, found in almost every country, filling up cavities, and constituting what is termed *bog*, is known. It is a product of vegetal origin, but differing from wood as well in the nature of the growth, as from the change which it has undergone atomically through the combined agency of time and pressure. It was once supposed that this formation was, in point of time, coeval with the disposition of the face of the country into hills and valleys; by some it was considered a bituminous deposit from the sea—the wreck of floating islands previous to the great convulsions which the earth underwent during the formation of the present continents and islands. By others it was even regarded as an organic substance in a state of vitality, and actually growing; but all these notions are now abandoned, and a more rational and philosophical view of its nature and production has been arrived at. From examining its structure, it has been found that it is constituted of vegetal matters, generally mosses and species of aquatic plants in different stages of decomposition; and from this circumstance, as well as from the general appearance of the localities where peat abounds, its formation is now accounted for in the following manner:—

At the present day it may be observed, that where pools collect, the soil under which is retentive, the water not being absorbed, stagnates, and, provided the surface evaporation is not great, forms a pond. Round the borders of this, various kinds of aquatic plants, sedges, rushes, *et cetera*, soon make their appearance, and by reproduction, gradually creep in towards the centre till the whole surface becomes covered. In course of time, when several races of these have succeeded one another, and mud and slime have accumulated at the roots and round the decaying stems, a spongy mass results, which is well calculated for the propagation of moss. Under a constant supply of moisture, these various species continue to luxuriate, and, by progressive growth and eremacausis, ultimately give rise to a composition in every respect similar to that constituting the various peat-bogs. That some such natural process has been the cause of the production of peat appears from its composition and the localities in which it is found. These are chiefly in the temperate zones, where evaporation is slow, and the atmosphere is generally more or less saturated with humidity. It may be conceived that in the origin of these formations, the retention of the water, whether from rain or springs, in extensive basins, led at first to the development of vegetal growth in the manner above indicated, and that the necessary moisture being supplied in abundance, the accumulation became so rapid, that ultimately the surface assumed the appearance of land; and, as decomposition proceeded, a degree of solidity was given to the mass to support denser bodies, such as shrubby plants. It would appear that this organic growth was rarely restricted to the original basin; but that, as it accumulated, it spread over adjacent land, which, in time, became a morass. Evidence conclusive enough of this exists in the fact, that whole forests, of almost every description, such as oaks, firs, ash, birch, yew, willow, *et cetera*, have been overwhelmed under its gradual but steady advancement, and are found in all positions at the bottom of peat-bogs. Generally, this formation is met with in climates of a moist nature, in level countries, where imperfect natural drainage exists, although it is found in considerable beds in upland districts. The very extensive peat moors on the coasts of the German Ocean, especially in Holland and Northern Germany, and in many tracts in Ireland and Scotland, are examples of the former; whilst the deposits encountered high up the Alps, in the Vosges, and in the Jura, illustrate the latter. In mountainous districts, in addition to the imperviousness of the rock to the moisture, the constant formation of clouds upon those elevated regions favors the growth of the mosses and plants, the decomposition of which contributes to the production of quagmires.

Darwin states that, in the Southern hemisphere, peat does not occur nearer to the equator than the latitude of 45°; that the composition there met with results from the decomposition of the plants and grasses. The circumstance that no mosses, so far as can be ascertained by strict examination, enter into the species of peat found in South America, favors this view.

The extent and depth of the peat-bogs vary considerably in the different countries where they are found, and depend on circumstances quite distinct from each other. It is evident that the area which they may occupy is intimately connected with the distribution of the water, from whatever causes. In Holland and North Germany, the water of the ocean seems to have largely contributed to the moisture in which they originated. The peat-moors of the Grand-duchy of Hesse would appear to be occasioned by the overflow of the Rhine, whereby these tracts were irrigated, and the waters remaining, and necessarily becoming stagnant, the place was soon changed, and, instead of remaining a swampy district, it ultimately became a morass. On the other hand, the thickness of the beds of peat, seems, from repeated observation, to be dependent upon the nature of the subsoil. Where the bottom is quartzose, the deposit is invariably not very thick; but if it be such as yields by disintegration a clayey coating, the depth and extent are much more considerable. The morasses of Holland are to a considerable extent about six feet in depth, as are likewise those in upland situations; whilst many of the peat bogs in Ireland are from thirty to forty feet in depth. On intersecting these, it appears from the fact of layers of gravel, clay, shells, *et cetera*, being interposed horizontally, that these tracts have been swept over with violent currents of water; such layers, however, are never more than a few feet in thickness, and, seem to have retained all the conditions favorable for the growth of the plants conducive to the formation of peat.

From its physical constitution, this substance may be regarded as a kind of fossil fuel, and, undoubtedly, it is one of the most extensive sources known. Viewing it as the product of the decomposition of plants carried on through a long succession of ages up to the present, it is natural to expect that when cut vertically, differences should appear showing the advancing state of decomposition. In every instance, almost, this progressive change is exhibited, and, consequently, peat is classed into—

Recent Peat and *Older Peat*, from the appearance it presents. The former bears distinctive traces of its origin in the roots, leaves, and stems of plants, the structure of which is still retained. It is very porous, tough, and elastic in some tracts; but in others, especially where the bog is well drained, very brittle. The color varies, with the age and the progress of the decomposition, from a light to a blackish-brown. In the second, to which the preceding gradually inclines, no traces of fibrous matters—such as roots, stems, or leaves—are observed, but it presents when cut a pitchy shining hue—is dense and fine in the grain. Preference has always been acceded to this as a fuel from its superior gravity, and the greater heat which it produces when undergoing combustion. From the change which the vegetals pass through, it is evident that the usual process of putrefaction is carried on in the ordinary way at the commencement; but as the surface grows, and contact with the air is cut off, the mass is left to the play of the affinity of its elements, rendered more active by the pressure which it has to sustain. The alteration is attended with the evolution of marsh gas—bihydride of carbon $C\ H_2$—and carbonic acid, in the same way as in every case of partial destructive distillation; but from the excess of moisture present, it is evident that this action cannot, in the case of peat, be so complete as in coal, which is analogous in nature. Many bodies are detected in peat, however, which are not contained in coal, although the ultimate elements of both are the same. Sprengel detected in peat considerable quantities of ulmic acid—known also by the names *ulmin*, *humus*, *gein*, and *geic acid*—the composition of which, as obtained from turf, is expressed by the formula $C_{40}\ H_{15}\ O_{12}\ N$; and when procured from mould, by $C_{40}\ H_{15}\ O_{14}\ N$. This principle is dissolved out by alkalies, and precipitated from their solutions by acids in brownish flakes; this, however, as also the other varieties of resins examined by Mulder, are of little use hitherto in the arts.

The density of peat varies with the relative position in which it is found, with the thickness of the stratum, and the amount of mineral matters which it contains. Freshly cut, it is saturated with water to the extent of eighty to ninety per cent. in some cases, and, when subjected to the ordinary process of air-drying, it retains a large quantity of this, amounting sometimes to thirty per cent.

The estimation of the gravity in this state would lead only to relative approximations, even if the per centage of moisture was known, and the species examined had undergone about the same degree of decomposition. As already intimated, however, the latter principally determines the difference of specific weight in peat from the same cutting. Karmarsh arrived at the following results with regard to Hanoverian peat:—

Species	Specific gravity.
1. Light-colored young grass peat, nearly unchanged moss,	0·113 to 0·263
2. Young brownish-black peat—an earthy matrix intersected with roots,	0·240 to 0·600
3. Old earthy peat without any fibrous texture,	0·564 to 0·902
4. Old or pitch peat,	0·639 to 1·039

Of twenty-seven samples of peat examined by Sir Robert Kane and Dr. W. K. Sullivan, the results, as stated in their report in 1851, show that the maximum density was 1·058, and the minimum 0·235, a great many being under 0·600, as may be seen from the following tabulation of their gravities, coupled with the constituents of the ash, to which reference will be made further on:—

	I.	II	III.	IV.	V.	VI.	VII	VIII	IX.
Specific gravity,	0·297	0·405	0·669	0·150	0·351	0·661	0·335	0·476	0·655
Potassa,	0·362	1·323	0·461	0·401	0·221	0·198	0·491	0·211	0·247
Soda,	1·427	1·902	1·399	1·330	0·712	0·590	1·670	0·651	0·496
Lime,	26·113	36·496	40·920	37·873	33·240	25·860	33·037	29·716	24·944
Magnesia,	3·392	7·634	1·611	5·127	1·904	1·207	7·523	1·204	1·285
Alumina,	4·180	5·411	3·793	0·271	0·240	0·371	1·686	0·298	0·360
Sesquioxide of iron,	11·591	15·608	15·969	14·802	12 760	18·746	13·281	20·372	19·405
Phosphoric acid,	1·461	2·571	1·406	1·257	1·222	0·874	1·438	1·066	0·242
Sulphuric acid,	12·403	14·092	14·507	11·814	21·470	23·630	20·076	22·664	10·742
Hydrochloric acid,	1·568	1·482	0·983	1·367	0·840	0·622	1·747	0·439	0·335
Silica in compounds decomposable by acids,	0·980	3·595	1·111	1·002	1·672	0·886	2·148	0·645	1·082
Sand and silicates undecomposable by acids,	22·519	2·168	2·107	4·722	13·147	14·430	7·683	11·180	26·789
Carbonic acid,	13·695	7·761	15·040	19·722	12·060	12·240	8·340	10·782	13·890
Total,	99·691	100·043	99·307	99·688	99·488	99·654	99·120	99·228	99·817

	X	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Specific gravity,	0·434	0·984	0·681	0·523	0·274	0·394	0·137	0·323	0·924
Potassa,	0·641	0·347	0·181	0·291	0·966	0·407	0·665	0·668	0·280
Soda,	1·875	0·679	0·550	0·586	1·038	2·074	2·605	1·709	2·180
Lime,	22·702	45·581	29·323	38·692	35·113	33·397	33·554	31·553	30·744
Magnesia,	6·809	1·256	3·425	2·372	4·687	11·293	9·229	9·439	9·237
Alumina,	1·109	0·129	0·672	0·408	1·627	1·627	0·677	1·707	2·027
Sesquioxide of iron,	29·854	15·974	19·095	15·537	14·322	18·500	18·366	6·012	19·7[illegible]7
Phosphoric acid,	2·019	0·188	0·975	0·878	0·828	0·744	1·300	1·286	1·2[illegible]
Sulphuric acid,	16·381	44·371	16·238	14·822	25·409	13·550	23·505	25·602	20·[illegible]57
Hydrochloric acid,	1·591	0·337	0·636	0·657	1·090	2·804	3·263	0·698	3·128
Silica in compounds decomposable by acids,	0·737	1·043	3·255	5·808	5·607	5·998	4·449	5·159	3·096
Sand and silicates undecomposable by acids,	14·505	2·653	8·884	14·181	4·340	6·593	3·040	6·282	3·163
Carbonic acid,	1·470	16·120	15·984	5·842	5·003	3·006	....	9·864	3·570
Total,	99 693	99·678	99·218	100·074	100·030	99·993	99·653	99·979	99·369

	XIX.	XX	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Specific gravity,	1.058	0·481	0·629	0·280	0·546	0·855	0·402	0·441	0·558
Potassa,	0·744	1·667	0·271	0·146	0·247	0·219	0·370	0·028	0·158
Soda,	0·704	2·823	1·491	0·466	1·150	0·855	2·628	2·832	0·527
Lime,	40·623	20·907	13·667	8·492	22·332	40·079	27·732	26·551	12·432
Magnesia,	4·352	15·252	16·994	4·702	5·608	4·035	6·875	12·580	3·095
Alumina,	1·671	2·034	0·259	10·705	0·932	0·895	1·521	3·298	5·991
Sesquioxide of iron,	10·368	17·040	26·644	15·052	29·970	14·160	7·451	12·116	30·725
Phosphoric acid,	1·114	1·447	1·339	1·557	0·699	0·632	1·670	2·0[illegible]2	0·526
Sulphuric acid,	24·208	23·375	22·691	13·974	31·612	22·295	20·389	22·401	14·518
Hydrochloric acid,	1·052	1·424	1·180	0·196	0·993	0·781	2·932	2·581	0·151
Silica in compounds decomposable by acids,	6·317	6·634	2·719	12·476	2·751	1·295	7·709	5·474	9·101
Sand and silicates undecomposable by acids,	3·710	10·682	11·373	31·198	3·775	5·496	10·088	17·711	22·721
Carbonic acid,	4·981	6·721	....	....	....	9·101	10·460	1·220	....
Total,	99·844	100·006	98·964	98·928	100·069	99·843	99·825	98·751	99·945

The carbonic acid found in the above analyses is, in nearly every instance, much less than what is required to saturate the lime, supposing the whole of the sulphuric acid to exist as sulphate of lime; this is accounted for by the high temperature necessary to incinerate the peat, having driven off the greater part of the carbonic acid.

I.—Light, spongy, surface-peat, of a reddish-brown color, and composed almost entirely of *Sphagnum*, species of which are still distinguishable; from near Monastrevin.

II.—Light surface-peat, of a reddish-brown color, containing small roots of *Erica*, also leaves of grasses and *Carex*; from Mount Lucas Bog, near Phillipstown, King's County.

III.—Rather dense peat, of a dark reddish-brown color, in which the structure of moss is still observable; from the same locality as No. II.

IV.—Light reddish-brown fibrous moss-peat, in which the *Sphagnum* is almost unaltered, as well as leaves of *Carex* and other plants, and the roots of species of *Erica*; from Twicknevin, Kildare.

V.—Upper layer of fibrous red bog, composed entirely of *Sphagnum*, *Hypnum*, and other mosses; from Derrymullen Station of the Irish Amelioration Society.

VI.—Dense peat, of a black-brown color, in which vegetal structure is nearly obliterated, but in which the leaves of grasses and *Carex*, with twigs of hazel and birch, are sometimes found; from Wood of Allen, Great Timahoe Bog.

VII.—Light surface-peat, of a pale yellowish-brown; from Wood of Allen. The mass is very open-grained and fibrous in this sample, and *Sphagnum* and *Hypnum* are readily distinguishable.

VIII.—Middle layer of the same bog, of a deep-reddish color. The mass is tolerably compact, but fibrous, having the structure of the mass very indistinct. A very few roots of *Erica*, and small twigs of birch and alder, and fir scales are found in it.

IX.—Lower layer of the same bog, and from the same locality. This variety is compact and dense, of a deep blackish-brown color, with an earthy almost conchoidal fracture, and exhibiting a resinous lustre when rubbed. Vegetal structure nearly obliterated.

X.—Good compact peat, of a blackish-brown color, and consisting principally of moss, with a number of *Erica* and grass roots and *Carex*. This sample is from Riversdale Bog, near Kimegad, and is used as fuel in Dublin.

XI.—An extremely hard and compact peat, having the vegetal structure entirely obliterated, and exhibiting when broken a resinous conchoidal fracture. Scales of fir-trees and twigs of birch and alder, *et cetera*, occur in it; it is a valuable fuel. Locality—Riversdale Bog, near Kimegad.

XII.—Very dense, dark, reddish-brown peat, from Anadruce and Cloncreim, on the Royal Canal. In this peat the vegetal structure is only occasionally perceptible.

XIII.—Rather dense peat, of a dark reddish-brown color and compact structure, from bogs of Rathconnell, Wood Down, and Great Down, near Mullingar. *Sphagnum* indistinct, but leaves of the flag and stems and roots of *Erica* occur in a very perfect state in it.

XIV.—Upper layer of a fibrous bog in the neighborhood of Banagher. It is a spongy mass, of a yellowish-red color, composed of almost unaltered *Sphagnum*, with occasional roots of *Carex*, *Erica*, *et cetera*.

XV.—Rather compact peat, of a reddish-brown color, from the same locality as the preceding sample. In this kind, vegetal structure is very perceptible, although undistinguishable; the roots of the *Erica* are abundant, but the greater part is evidently derived from moss.

XVI.—A more compact peat than No. XV., from the same bogs, consisting of fibrous or red bog, of a light reddish-brown color. Like the foregoing, the species is indiscernible in this, although organic structure is visible. Roots and leaves of *Carex* are exceedingly abundant in it.

XVII.—Light surface-peat, of a pale reddish-brown color, from the bogs of Clonfert and Kilmore, at the mouth of the Suck, near Banagher. The mass is spongy, and is composed of almost unaltered *Sphagnum*, with a few stems and roots of *Erica*.

XVIII.—Peat from the same locality. It is rather compact but fibrous, and of a light reddish-brown color passing into black.

XIX.—An exceedingly dense peat, of a conchoidal earthy fracture, from Athlone bog. In this the vegetal structure is almost completely destroyed; but when apparent, indicates remains of *Carex*, grasses, and *Erica* in abundance.

XX.—A rather dense peat, of a blackish-brown color, in which the structure of moss is no longer visible, but abounding in remains of *Carex*, grasses, and roots and stems of *Erica*; from the Curragh or Clonbourne bogs near Shannon Bridge.

XXI.—A dense peat, of a dark reddish brown color, from bogs along the Shannon. Remains of *Carex* and grasses are abundant in this variety, but *Sphagnum* is very indistinct. It is used in steamers plying on the river.

XXII.—A light fibrous peat, of a reddish-brown color, formed evidently of a great number of plants, and in which the structure of moss is very distinct. Species of *Sphagnum* and *Hypnum* are observed, and also remains of *Carex* and grasses, the roots of *Erica*, the bark of birch, and probably alder-twigs in abundance. It is from the same locality as No. XXI.

XXIII.—A very dense peat, of a blackish-brown color, of a compact though very indistinct structure. The remains of *Carex* are abundant, as also roots of *Erica*. It forms an excellent fuel. Locality the same as No. XXI.

XXIV.—A very dense blackish-brown compact peat, from the same locality as No. XXI. In this species, vegetal structure is almost obliterated. It has an earthy fracture, and is full of the tubes of the bark of hazel, birch, and alder; occasionally scales of pine bark and leaves of *Carex* and grass are met in it.

XXV.—A rather dense reddish-brown peat. The structure of this is indistinct, but altered *Carex* leaves and fragments of twigs and roots are observed in it. Locality the same as No. XXII.

XXVI.—Rather compact and moderately dense peat, of a dark reddish-brown color. Structure of moss almost obliterated. Fracture earthy. Abundance of leaves, stalks, and roots of grasses, *Carex*, *et cetera*. Same locality as No. XXII.

XXVII.—A dense jet-black peat. Structure of moss completely destroyed. Fracture earthy, tending to conchoidal; assuming resinous lustre when rubbed. Abundance of remains of *Carex* leaves, and a very few fragments of bark, apparently of hazel. Same locality as No. XXII.

From the results of the ultimate analysis of dried peat, it is observed that the numbers which are found do not correspond with the analysis of dried wood. The following analyses by REGNAULT and MULDER show the centesimal contents of carbon, hydrogen, and oxygen:—

Locality.	Carbon.	Hydrogen	Oxygen.	
Vulcaire,	59·57	5·96	34·47	Regnault.
	60·40	5·86	33·64	Mulder.
Long,	60·06	6·21	33·73	Regnault.
	60·89	6·21	32·90	Mulder.
Champ de Feu,	60·21	6·45	33·34	Regnault.
	61·05	6·15	32·50	Mulder.
Friesland,	59·42	5·87	34·71	"
Friesland,	60·41	5·87	34·02	"
Holland,	59·27	5·41	35·35	"

In these samples, the numbers are calculated after deducting the ash. It is a well-ascertained fact that a greater or less quantity of nitrogen is invariably contained in peat, but this element appears to have been overlooked in the preceding. To show the average extent of the contents of nitrogen, the following analyses, selected from the *Dublin Journal of Industrial Progress*, so ably edited by Professor SULLIVAN, are submitted. The materials were taken from the same localities as mentioned in the foregoing table; but before subjecting them to analysis, they were thoroughly exsiccated at a temperature of 220° Fahrenheit:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen, mean.	
Surface-peat, Phillipstown,	58·694	6·971	32·883	1·4514	Kane and Sullivan.
Dense peat, Do.,	60·476	6·092	32·516	0·8806	
Light surface-peat, Wood of Allen,	59·920	6·614	32·207	1·2588	
Dense peat, Do.,	61·022	5·771	32·400	0·8070	
Surface-peat, Twicknevin,	60·102	6·723	31·288	1·8866	
Light surface-peat, Shannon,	60·018	5·875	33·152	0·9545	
Dense peat, Do.,	61·247	5·616	31·446	1·6901	

Annexed are further analyses referring to the same subject by KANE and RONALDS:—

	Carbon	Hydrogen.	Oxygen.	Nitrogen.	
Kilbeggan, Westmeath,	61·040	6·670	39·47		Kane.
Kilbaha, Clare,	56·630	6·330	34·48		
Cappoge, Kildare,	51·05	6·850	39·55		
Ochta, in Eastern Russia,	39·084	3·788	51·088		Woskressensky.
Peat 4·5 feet from surface, Tuam, Ireland,	57·207	5·655	28·949	3·067	Ronalds.
" 3·5 feet " "	58·306	5·821	29·669	2·509	
" 4·5 feet " "	59·552	5·502	28·414	1·715	

Comparing these numbers with those afforded by dry wood, it would appear—viewing the peat as a compound of equal weights of water and carbon, and supposing that the oxygen in the wood is proportioned to the hydrogen to form water—that an excess of ten per cent. of carbon and two per cent. of hydrogen is contained in the peat over the quantity of these elements which wood affords, but the amount of water is reduced ten per cent. This difference in the centesimal amount of the elements might have arisen from the decomposition which the matter of the peat has undergone.

Peat always contains earthy matters in greater or less proportion according to the thickness of the stratum and its position. Surface-peat generally contains less mineral matters than the second strata, which often possesses so much of these as to render it useless in point of economy as fuel. In this, as well as from the nature of those matters, it essentially differs from wood. These substances are left when the peat is consumed in contact with air in the form of ash, and, from the nature of the ingredients, it presents various appearances from white to grey and ochrey. The per centage of the ash left when peat is burned is given in the annexed table, which embraces almost every variety of this substance:—

Variety of Peat.	Ash.	Observer
Grass peat—brownish-yellow,	1·0 — 1·5	Karmarsh.
Pitch peat,	1·2 — 8·0	
Young peat—dark-brown,	5·0 — 7·0	
Old earthy peat,	10·0	
Black firm peat, from Neumünster,	2·2	Suersen.
" " Sindelfingen,	7·2	Schübler.
Brown loose peat, from Schwenningen,	2·3	
Very old peat, from Vulcaire, near Abbeville,	5·58	Regnault.
" " Long, "	4·61	
Peat not so old, from Champ de Feu, near Abbeville,	5·35	
" from near Berlin, 1st stage,	9·30	Achard.
" " 2d "	10·20	
" " 3d "	11·20	
Black old peat, from Möglin,	14·40	Einhof.
Young brown peat,	14·30	
Moor in Eichfeld, 1st sort,	21·50	Buchholz.
" 2d "	23·00	
" 3d "	30·50	
" 4th "	33·00	
Ash in forty-one sorts, from the Erzgebérge,	1·00 — 24·0	Winkler.
" three varieties, from Holland and Friesland,	4·61 — 5·580	Mulder.
" twenty-seven varieties, from the central Bog of Allen in Ireland,	1·120 — 7·898 mean 2·62	Kane and Sullivan.
" three varieties, from the neighborhood of Tuam in the west of Ireland,	3·695 — 4·819 mean 4·545	Ronalds.
" nine varieties, from Schnaditzer bog, near Schwemsal, in Saxony,	5·300 — 37·10 mean 18·47	Wellner.

Thus it will be seen, that in some of these varieties no less than one-third of the entire weight consists of incombustible substances, which, it is needless to say, is too large a quantity, and prevents their being much employed as a source of heat. Such varieties are, however, valuable as manures, owing to their containing a large amount of phosphates and other salts, that serve to enrich the soil.

Very copious details of the composition of the ashes of most of the peats of Ireland have been given in a former table, at page 52, to which the reader is referred.

Peat, when distilled in close vessels, gives off various products similar to those which wood affords, besides ammonia, and some bodies of a fatty nature, which are much in demand in many departments of the industrial arts. In its natural state it is highly antiseptic, to which may be attributed the long period which is required before the traces of the substances originating it are effaced. This quality has been further proved by the wood which is found without being in the least injured, although buried thirty feet deep in it for centuries. Not only these, but human bodies and remains of animals—the latter now extinct—and other substances prone to putrefaction, have been found at a great depth in a high state of preservation.

Where peat bogs abound, as in those countries already alluded to, the inhabitants make use of the article, after undergoing a very simple preparation, as fuel for domestic uses. With the exception of a few localities on the Continent, but little has been done to bring peat into requisition in those arts which are intimately associated with heat, although the value of the charcoal which the substance affords as a calorific agent has been attested by practical skill and theoretical calculations. Attempts have long been made in Holland and some states of Germany, to render peat more profitable, as well in manufacturing operations as for domestic purposes; but it is remarkable that in a country such as Ireland, where, compared with other nations, the cost of labor is low, with one exception nothing has been done to convert her area of *two millions eight hundred and thirty thousand acres* of the finest bogs in the world to her advantage, although, if properly treated, they might prove a source of immense wealth. This neglect of the national interests seems still more inexplicable, when it is considered that the wealth requisite for successful manufacturing enterprise is already in the hands of the people, but lies a mere waste, useless to the possessor and to the universal interests of the community. It would appear, however, that something like an incipient spirit of enterprise is growing in the Irish mind, and, if this be fostered by the hand of science, doubtless, ere long, many of the hidden treasures which lie at the feet of the impoverished population, will be developed to the advantage of the parties immediately concerned, and the prosperity of the nation at large.

For domestic purposes, the peat is prepared by a very simple course of operations, differing sometimes according to its nature and thickness.

In every case the surface layer, which contains the living plants and their roots in the natural state, is stripped off to the depth of six to nine or twelve inches. The material is then cut with a kind of spade known as the *slane*, which has a wing bent at right angles to the blade of the instrument, so as to form with the latter two sides of a square. Sometimes two such wings or ears are added to the tool, and at the outer end these are united by a plate of iron which gives to it the appearance of a hollow rectangular cube, open at both ends. By this instrument the peat is cut in long square masses, and then spread upon the sward, where it spontaneously loses its water. After the bricks have acquired sufficient consistency, they are piled up on end so as to afford a more thorough exposure to the air; and finally, when desiccation has advanced, the turf, as it is then called, is piled together, being built round by a kind of clamp construction of the sods or bricks, and left till the material becomes as dry as it can be made by exposure to the air. Such is the mode adopted when the peat is sufficiently elastic to bear being so handled without breaking; when, however, the material is brittle and will not admit of being used in this way, it is dug out with ordinary spades, shovels, *et cetera*, and all roots, stones, and such like solid bodies picked out. It is then spread in a layer of from twelve to eighteen inches in thickness, watered, and brought to a homogeneous mixture, either by the tramping of men or beasts, where the latter can be employed. Afterwards the surface is smoothed and moulded in forms, either with the hand or a small mould which indents the surface. When the excess of water has drained off and the peat becomes consistent, the bricks are cut out with a long knife, and dried in the manner already indicated. In many moors or fens the peat is so surcharged with water that it cannot be extracted even with the spade; in this case the workmen employ a kind of dredge, by which the material is collected. It is deposited on a sloping sward, and after the superabundance of water has drained off and the mass becomes more consistent, it is moulded into bricks. The latter processes are usually resorted to in France, Germany, and most other localities where peat abounds. In Holland a different course is pursued, which, though more circuitous, is notwithstanding more effectual in producing a denser fuel than can be obtained by the foregoing methods. The upper stratum, which is light and fibrous in its nature, is nearly always moulded with the slane, though sometimes it is subjected to the same operations as the under layer. Generally, this is scooped out with a kind of ladle when it is not too wet, and carried to the tempering ground; where, by sprinkling with water, tramping with the feet, and tempering with a rake, it is brought to a homogeneous consistence, and freed from stones, bits of wood, leaves, and the like. In case the matter is slimy, and so thin that it will not admit of adhering together in masses, another kind of tool is employed, enabling much more peat to be abstracted, with less water, than if the ordinary iron ladle dredge were used. It consists of a ring of iron, the edge of which is sharp, attached to a long handle; the side of this band is perforated for the purpose of affixing the body, which is a thick cloth, and the whole forms an instrument not unlike a fisherman's landing-net. Much more peat is taken up by this, and the excess of water filtering through the meshes of the tool, the peat is in a state which will admit of being immediately worked. This very slimy material is kneaded in a kind of trough or tub, till it becomes thoroughly blended together. In this state it appears like a kind of mortar. The next operation is to prepare the sward on which it is to be spread. This is done by laying upon it a covering of hay, which is trodden down to a level, whereon the peat is spread to the depth of a foot or more. The depth is regulated by means of planks or boards set in parallel lines, and placed, as circumstances may admit, from twelve to thirty feet apart. It is usual to beat down the surface of these beds to give the peat an uniform thickness. After a few days, when the excess of water has, partly by draining off, partly by infiltrating into the soil, and partly by evaporating, disappeared, and the layer of matter has acquired a certain consistence, it is rendered more compact by treading. This part of the work is performed by women and children, who attach flat boards, about six inches broad and twelve to fourteen long, to their feet. Before this treading is finished, the peat has acquired such solidity that it will bear a person's weight upon it without sinking. The surface is again brought to a level by beating it with oars, shovels, and the like; and after this is accomplished, the surface is divided into squares, the sides of which are about four to five inches. When the tracings thus made are cut, the bricks are about eight inches long by four to five inches square in the section. The drying is performed by placing alternate rows crosswise upon one another, reversing this order in a few days, and continuing the exposure till the most of the moisture has disappeared. When this is the case, the turf is stored for use, but it is necessary that the moisture be sufficiently expelled before this part of the business is performed, as according to Dumas, when this is not effected, the stacks are liable to a fermentative process which raises the temperature so high as often to cause spontaneous combustion. It has been already stated, that one essential quality of peat, in relation to its value as a fuel, is its density and freedom from large quantities of mineral matters; but another is also required, namely, that it contains as little water as possible. However well exposed or prepared, air-dried peat always retains from twenty to thirty per cent. of moisture, and this expends a considerable quantity of the heat of combustion in its evaporation. When intended for particular purposes, such as for charring in heaps, for lime-burning, and such like purposes where it is to be piled up in large masses, or has to resist much pressure, the value of the material is enhanced by the quality of strength or solidity, because, if it were very brittle, it would prove almost valueless for either of these uses.

Compression of Peat.—The relative heating power of dense peat well dried is about the same as wood, and half that of coal; the lighter kinds prove to be not more than one-third as effectual as coal for heating. Prepared according to the improved processes which have lately been introduced, it gains considerably in calorific power, as much more combustible material is contained in compressed peat, bulk for bulk, than in the ordinary sods or moulded turf. Much difficulty, however, stands in the way of effecting this condensation of the article, owing to the elastic nature of the fibre, which causes a distention after the force is removed. The system of pressing each sod or mould, as in the preparation of artificial fuels, would never answer with peat, as the labour would be too great in proportion to the value of the material; and, besides, the supply which could be so furnished would be inadequate to the demands of a large consumption. This led Mr. Williams, a gentleman who has contributed much to the development of the industrial uses of peat in Ireland, to the adoption of powerful hydraulic presses, which, while they are able to overcome the elasticity of the material, can supply it in considerable abundance. It is questionable, however, if his endeavors have been remunerative, as it is difficult to eradicate the preconceived prejudice of manufacturers and traders against this species of fuel. The manner of compressing, as conducted in the Cappoge works, was to break up the fibre of the peat as much as possible after cutting, and then to place it interlaid with coarse cloths or coco-matting under the machine. After the action had been exerted during the period allowed, the material was found to be reduced to one-third its original volume, and to have lost about two-fifths of its weight. In this state, the peat, when thoroughly dried, is not so hygroscopic as when the drying is conducted in the open air and no pressure exerted, and the lighter kinds yield by compression a substance denser than wood; the lower stratum affords a product still more so. The elimination of the water by pressure improves the quality of the peat in other respects, not the least of which is the reduction of the relative amount of mineral matters contained in it, for considerable quantities are carried off in the water that would remain if it were exposed to spontaneous exsiccation. It would appear that the increased expense of this process is immaterial, when the relative volumes of product it affords, compared with ordinary peat, and the large per centage of water which the latter contains, are considered; for, whereas the latter costs three shillings and sixpence per ton at the bog, the prepared article can be had at five or six shillings. Mr. Cobbold's method is to convert the peat into a magma, with the addition of water if necessary, and when by means of *centrifugal* power this is subsequently got rid of, a very dense product is obtained. The course recommended by Mr. Stone as described in his patent, sealed in March 1850, is the use of a box divided into a number of compartments suited to the size of the machine, and pressure to be exerted upon this, by rollers adapted to one another by means of leverages. Figs. 38 and 39 are vertical and side views of this arrangement, where the same letters indicate similar parts in each figure. A and B are cast-iron rollers, the latter of which is fixed in a stationary bearing, C. D is an adjusting screw, by means of which the roller may be raised or lowered at pleasure; this screw works in the lever, F, the fulcrum of which is at the top of the side frame, and the handle connected with the long one, H, by the rods, I I, which are adjusted by the screw, K. Pressure is exerted upon the lever, H, by sliding the weight, J. The friction rollers are shown at L L L L, for supporting the pressure box, M, before or after it has passed the pressure rollers, A B. Upon the shaft of the latter, two toothed wheels, P P, are fixed, which are worked by two pinions, N N, upon the shaft, O; the wheels, P P, gear into two toothed racks at each side of the pressure box, and serve to carry it along under the pressure rollers already indicated.

Fig. 38.

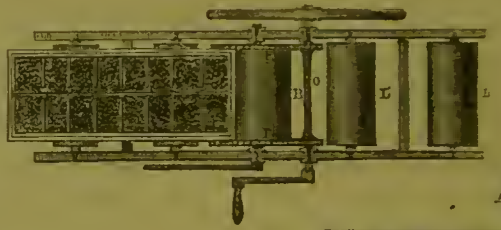
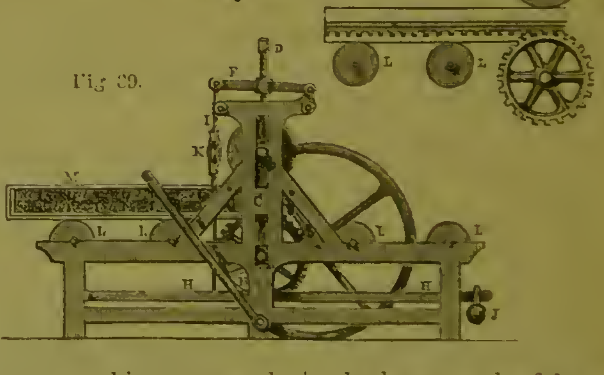


Fig. 39.



The box is such that it contains another one, E, in which the peat is condensed; this is divided into sixteen compartments by means of bevel-edged knives, *a a*, fixed transversely in the cover, and *b b* in the bottom, and so corresponding with one another that when pressure is exerted they are nearly in contact. The longitudinal knife in the middle separates the interior into two divisions.

Motion is given to the whole by means of a winch-handle and fly-wheel appended to the ends of the shaft, O; when the motive is steam, the handle is substituted by a drum on which a strap works. The lever, H, may be lifted by means of another lever shown in the figure, so as to remove all pressure. The method of operating with this machine is to fill the movable box with peat, after which it is placed inside the box, M; the lever, H, is raised, and the box is drawn forward by putting the shaft, O, in motion. When it has come under the roller, H is let down so as to bring A in contact with the lid of the box. From the time that the verge of the box has entered under the roller till it has passed the centre, the lid is in an inclined position, varying from an angle of 10° or 15°. At the time the roller is at the centre, the cover will have assumed a horizontal position, and a uniform pressure will be enforced upon the entire contents. When the box has passed through the roller, the lid is taken off, and the compressed material removed and exposed to thorough desiccation. The compartment is again filled, the cover fitted on, and, by reversing the motion of the handle, the box is made to pass the same way backwards. Thus the compressed material is discharged at each end of the machine.

These and a few others are the means hitherto proposed for improving the quality of peat fuel, so as to remove its characteristic fault, namely, want of density; but it seems that as yet the processes have not been conducted with sufficient spirit, or the outlay in machinery is too great in proportion to the value of the material operated upon. It appears that in Ireland the chief improvement in this process must, for some time to come, turn upon the system of drying under sheds, so as to protect the peat from the influence of the rain, a considerable quantity of which it is capable of absorbing, and yet will appear dry to the touch. The amount of water thus retained considerably diminishes the heating power of the turf. This will be seen more clearly from the following data:—When a pound of pure dry peat is burned, and the entire amount of caloric which it yields is conducted through water, it will be found that six times its weight of this liquid will be raised to 212°. In ordinary turf the fourth part of the weight is water, so that there is only three-fourths available as a heating medium. Were a pound of this consumed in the same manner as the foregoing, it is evident the caloric developed would raise only four pounds and a half to the boiling point. This quantity would, of course, evaporate the water contained in the peat, so that the visible effect would be as four and a quarter to six, or about thirty per cent. in favor of the dried material. Such a wide difference, it is needless to say, is sufficient cause for condemning the moist material even for domestic use, but especially in manufactories, where it is an object of the first importance that the fuel should exert the greatest possible effect in proportion to its bulk and value.

Before passing to the discussion of the action of heat upon peat, it will be well to devote a little attention to the consideration of the nature of those substances contained in it, as well as those which are artificially produced from it. It has been stated already—page 51—that by the action of alkalies upon peat, the greater part is dissolved, and that, when the liquor is further treated with acids, the *ulmin* is precipitated in flakes. This substance, which is the principal and most important component of peat in its ordinary state, is so analogous to woody fibre in its composition, that the changes which the material producing it has undergone, may be considered as sufficient to account for the difference. By the researches of BRACONNOT and others, it has been proved that in the fresh peat *ulmin* is combined with lime, and forms therewith a true chemical compound—ulminato of lime. Ulmin or humus, popularly termed vegetal mould, has the following composition when prepared from wood and sugar:

	From Wood.	From Sugar.
Carbon,....................	72·7	65·65
Hydrogen,..................	6·1	4·28
Oxygen,....................	21·2	30·07
	100·0	100·00

When peat is subjected to destructive distillation ammonia is invariably one of the products, a circumstance for which it is difficult to account, seeing that ulmin is entirely devoid of nitrogen, unless it be admitted that, during the progressive decomposition of that body, nitrogen is assimilated from the air, just in the same manner as decaying wood or vegetal matter takes up the same element. In the course of the decomposition of vegetal bodies, oxygen and nitrogen are absorbed and combined with the other elements, and the consequence is the formation of a new substance called by HERMANN *nitrolin*—a body that approximates closely in its composition to animal flesh. Such a metamorphosis may be explained by supposing that two equivalents of woody fibre take five equivalents of nitrogen and ten of oxygen from the atmosphere, and give off sixteen equivalents of carbonic acid; thus—

$$
\begin{array}{rl}
\text{2 Eqs. of Woody fibre} & = C_{72}\ H_{48}\ O_{48} \\
\left.\begin{array}{r}\text{5 Eqs. of Nitrogen and} \\ \text{10 Eqs. of Oxygen}\end{array}\right\}\ \text{added} & = \phantom{C_{72}\ H_{48}\ } O_{10}\ N_5 \\
\hline
& \ C_{72}\ H_{48}\ O_{58}\ N_5 \\
\text{16 Eqs. of Carbonic acid deducted} & = C_{16}\ \text{—}\ O_{32}\ \text{—} \\
\hline
\text{Nitrolin,} \ldots\ldots\ldots\ldots & \ C_{56}\ H_{48}\ O_{26}\ N_5
\end{array}
$$

By a further change these elements are disturbed, and carbonic acid is produced together with ammonia. Besides these, several other new substances of a brown or black color remain, among which are ulmic acid, *et cetera*. DUMAS supposes that the ammonia results from the decomposition of animal remains embedded in the marshes; but the Editor is of opinion that it is mostly derived from the atmosphere.

When peat is exposed to the action of heat in close vessels, it affords a variety of substances, the principal being pyroligneous acid; a brown empyreumatic crystallizable oil, from which numerous products may be extracted, and among them paraffin; carbonic oxide and carbonic acid, hydrocarbon gases, together with a variable quantity of ammonia. Industrial progress has invested several of these with a new value during the last few years, so much so that they have become special objects of manufacture. This has been shown under the heads ACETIC ACID, AMMONIA, ASPHALT, CANDLES, *et cetera;* and with regard to certain inflammable gases and other bodies, their importance will appear further on. The products of the distillation of peat are all useful in the arts, and consequently are in constant request. To provide them in sufficient quantity, or at least in some degree to supply the wants of the trades using them, a manufactory was erected a few years ago near the town of Athy, in Kildare, Ireland, for the purpose of distilling peat, and obtaining the useful products which it affords. This manufactory has now established itself, although it had many difficulties to contend against. It is worked on the principle of Mr. REES REECE's patent, sealed in 1849. The idea was derived from the application of inflammable gases to heating purposes by the late M. EBELMEN, for the utilization of inferior coals and other combustibles, by converting them into gases, the object being the production of those organic bodies already alluded to. These are produced in greater abundance from peat than from other combustibles, owing to the large amount of water in it, which keeps the temperature low during the distillation, and thus favors the formation of such products. The principle of the distillation is the introduction of a blast of air at the bottom of a furnace filled with the combustible. The heat developed in this part passing up with the gases through the mass, causes the destructive distillation of the latter, and the expulsion of the empyreumatic products with the combustible and other gases from the fire. By proper contrivances these are operated upon, in such a way that all the condensable substances are removed, and the inflammable products which cannot be liquefied are employed to heat boilers, stills, or evaporating pans required in the purification of the crude products. It is this application of all the products to economical purposes which renders the manufactory so novel in its nature, for the very substance operated upon is made to supply all the requisites for carrying out the manufacture, besides supplying the useful products.

For the following important details with reference to this manufactory, the Editor is indebted to the *Journal of Industrial Progress*, by Professor SULLIVAN :—

From repeated examinations of peat with reference to the amount of tar, oils, paraffin, and ammoniacal salts which it yields, as well as from the researches of the patentee, most flattering results were anticipated from the development of this branch of industry. To carry it out, a company was organized, called the IRISH PEAT COMPANY, which stated in its prospectus that, by a manufactory capable of operating on one hundred tons daily, or thirty-six thousand five hundred tons annually, the following commercial results would be attained; namely,—

EXPENDITURE.

36,500 tons peat, at 2s. per ton,	£3.650
455 tons of sulphuric acid, at £7 per ton,	3.185
Wear and tear of apparatus, *et cetera*,	700
Wages, labor, *et cetera*,	2.000
Freight and incidental charges,	2.182
	£11.717

PRODUCE.

365 tons of sulphate of ammonia, at £12 per ton,	£4.380
255 tons of acetate of lime, at £14,	3.570
19,000 gallons of naphtha, at 5s.,	4.750
109,500 pounds of paraffin, at 1s.,	5.475
73,000 gallons of volatile oil, at 1s.,	3,650
36,000 gallons of fixed oil, at 1s.,	1,800
	23,625

leaving a net profit of £11.908, or a fraction more than a hundred per cent. The cost of the manufactory for working such a quantity was stated to be about ten thousand pounds. That peat, and other substances heretofore useless, should be productive of a trade so profitable, was more than could well be credited by the parties wishing to embark in the speculation; and to satisfy themselves on this point, a series of experiments was instituted in the laboratories of the Museum of Irish Industry, under the superintendence of Sir ROBERT KANE and Professor SULLIVAN. These were conducted upon specimens of peat from various peat deposits in Ireland in a twofold manner: firstly, by distilling the peat in close vessels, and secondly, by effecting the distillation by a combustion of a part of the material with a blast of air, as proposed in the manufactory.

In operating by the former method, a retort was used similar to that employed in the distillation of coal in the manufacture of gas. To the exit pipe from this retort a series of WOULFE's bottles were adapted, wherein the greater portion of the tar and other aqueous products were deposited, the remainder being condensed in a worm fixed in a barrel of water, and the permanent gases collected. In each trial one hundredweight of peat was worked off in eight to fourteen charges, according to the density of the substance. The annexed table represents the quantity of the gross products obtained :—

No of Experiments.	Locality whence obtained.	Water.	Tar.	Charcoal.	Gas
1. 2.	Surface peat, } A mixture of about equal parts of the two peats, from Dense peat, } Mount Lucas Bog, near Phillipstown,	23·600	2·000	37·500	36·900
3.	Light surface peat, from Wood of Allen,	32·273	3·577	39·132	25·018
4.	Black compact peat, from do.,	38·102	2·767	32·642	26·489
5.	Surface peat, from Ticknevin,	38·628	2·916	31·110	32·346
	Do. distilled with the retort heated to a very bright redness,	32·098	2·344	23·437	42·121
6.	Surface peat, from Shannon,	38·127	4·417	21·873	35·693
7.	Dense peat, from do.,	21·189	1·462	18·973	57·746
	Average,	31·378	2·787	29·222	36·616

The amount of ammonia, acetic acid, and naphtha, contained in the aqueous product, was next determined, as well as that of the oil and paraffin in the tar; the following table contains the results obtained:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, NAPHTHA, ACETIC ACID, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT.

Locality whence obtained.	Ammonia.		Acetic Acid.		Pyroxylic spirit or naphtha.	Paraffin.	Volatile oil.	Fixed oil.
	Ammonia as NH_3.	Corresponding quantity of sulphate.	Acetic acid as $C_4H_3O_3, HO$.	Corresponding quantity of acetate of lime.				
1. Surface peat, 2. Dense peat, { A mixture of equal parts of both peats from Mount Lucas Bog, Phillipstown, }	0·302	1·171	0·076	0·111	0·092	0·024	0·684	0·469
3. Light surface peat, Wood of Allen,........	0·187	0·725	0·206	0·302	0·171	0·179	0·721	0·760
4. Black compact peat, do., ...	0·393	1·524	0·286	0·419	0·197	0·075	0·571	0·565
5. { Surface peat, from Ticknevin,...........	0·210	0·814	0·196	0·287	0·147	0·170	1·262	0·617
Do. distilled with the retort heated to redness,................ }	0·195	0·756	0·208	0·305	0·161	0·196	0·816	0·493
6 Surface peat, from Shannon,.............	0·404	1·567	0·205	0·299	0·132	0·181	0·829	0·680
7. Dense peat, do.	0·181	0·702	0·161	0·236	0·119	0·112	0·647	0·266
Average,........................	0·268	1·037	0·191	0·280	0·146	0·134	0·790	0·550

In the second series of experiments, in which the peat was consumed by igniting it, and then supporting the combustion by a blast, the same peats were used as in the foregoing tables. The annexed table shows, however, only the products obtained from those which in the former experiments exhibited the greatest dissimilarity, this being sufficient for the purpose of comparison:—

Character of Turf, and Locality whence obtained.	Water.	Tar.	Ash.	Gases.
Light surface peat, from Wood of Allen,.........	31·678	2·510	2·493	63·319
Dense peat, do.	30·663	2·395	7·226	59·716
Dense peat, from the River Shannon,............	29·818	2·270	2·871	65·041

The amount of ammonia, acetic acid, naphtha, paraffin, and oils, obtained in the same way, and expressed in the following numbers, affords a comparative view of the merits of both methods of working:—

TABLE REPRESENTING THE PER CENTAGE OF AMMONIA, ACETIC ACID, NAPHTHA, PARAFFIN, AND OILS, OBTAINED BY THE DISTILLATION OF PEAT IN A BLAST OF AIR.

	Ammonia.	Acetic acid	Naphtha.	Paraffin.	Oils.
Light surface peat, Wood of Allen,.............	0·322	0·179	0·158	0·169	1·220
Dense peat, do., ...	0·344	0·268	0·156	0·086	0·946
Dense peat, from the River Shannon,...........	0·194	0·174	0·106	0·119	1·012
Average,...................... ..	0·287	0·207	0·140	0·125	1·059

The average results of both methods of operation gave for the distillation in close vessels—

	Average.	Maximum.	Minimum.
Aqueous products,.	30·614	32·678	29·818
Tar,.............	2·392	2·510	2·270
Gases,......	62·392	65·041	59·716
Ashes,...........	4·197	7·226	2·493

The watery products and tar afforded—

	Average.	Maximum.	Minimum.
Ammonia,...........	0·287	0·344	0·194
or as Sulphate of ammonia,..	1·110	1·330	0·715
Acetic acid,..........	0·207	0·268	0·174
or as Acetate of lime,......	0·305	0·393	0·256
Naphtha,............	0·140	0·158	0·106
Volatile and fixed oils,	1·059	1·220	0·946
Paraffin,............	0·125	0·169	0·086

Placing these numbers in apposition, the following will express the relative value of the two modes:—

	Average produce from close distillation.	Average produce from distillation in blast of air.
Ammonia,................	0·268	0·287
or as Sulphate of ammonia,......	1·037	1·110
Acetic acid,..............	0·191	0·207
or as Acetate of lime,..........	0·280	0·305
Naphtha,.................	0·146	0·140
Oils,....................	1·340	1·059
Paraffin,.................	0·134	0·125

The similarity of these numbers shows that very little difference exists between the results obtained from the distillation of the substance in close vessels, and from its decomposition in the fire by a blast of air. In the first case, however, there remains an average of twenty-nine parts of charcoal, which might determine a preference for that method, were it not that the greater part of this is consumed in carbonizing the matter in the retort.

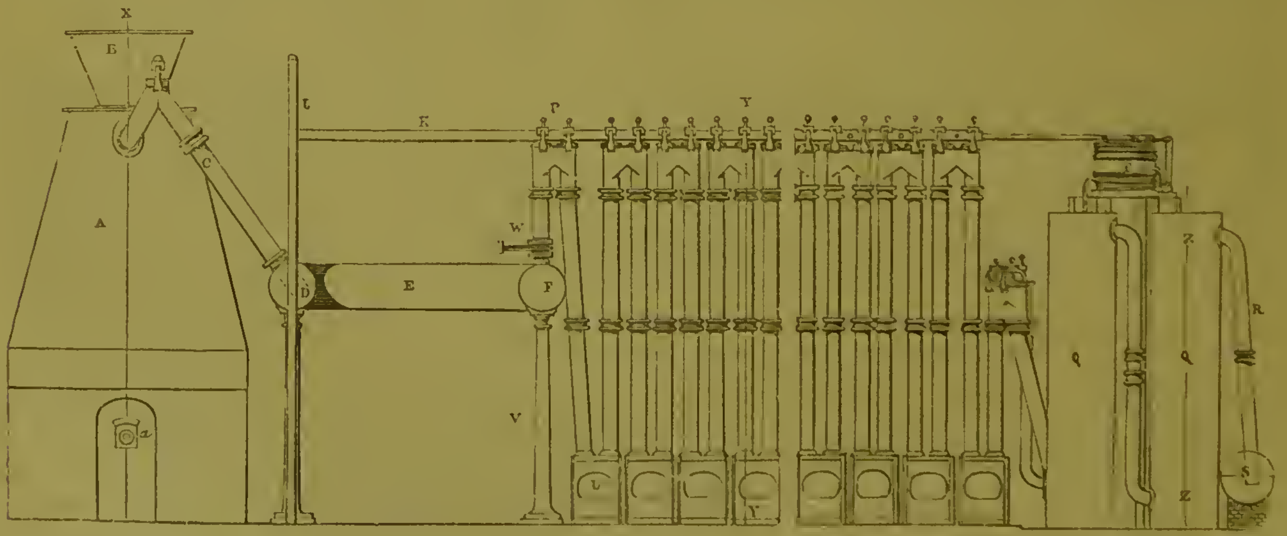
A similar and independent series of experiments was conducted by Dr. HODGES, whose results are appended below, and contrasted with those arrived at by Professors Kane and Sullivan, as well as with those forming the basis upon which the company's prospectus was founded:—

	Kane and Sullivan.		Hodges.		Statement in Company's Prospectus.	
	Per ton	Per cent.	Per ton.	Per cent.	Per ton.	Per cent.
Sulphate of ammonia,	24 3/10 lbs.	1·110	22 3/4 lbs.	1·000	22 2/5 lbs.	1·[illegible]
Acetic acid—real hydrated,	4 2/3 "	0·207	7 1/4 "	0·328	— "	—
or as						
Acetate of lime,	6 4/5 "	0·305	— "	—	nearly 15 7/10 "	0·7[illegible]
Wood naphtha,	50 1/2 ozs.	0·140	83 1/4 ozs.	0·232	66·5 ozs.	0·185
Tar,	53 3/4 lbs.	2·390	99 1/2 lbs.	4·440	—	—
Products of the tar, Paraffin,	2 1/5 "	0·125	—	—	3 lbs.	·164
Products of the tar, Oils,	nearly 2 2/3 galls.	0·159	—	—	2 1/2 galls.	·071

If the difference of the peat in these experiments be taken into account, the results of the three columns will be nearly equal; for in Hodges' experiments the peat was of a black unctuous nature, weighing, per cubic yard, from five and a half to six and a half hundred-weight.

At first, the apparatus erected for the distillation, *et cetera*, was on a small scale, and not so much with the object of realizing an immediate profit, as with a view to the perfection of the process by which the operation might be conducted on a scale of greater magnitude. During this preliminary phase of the undertaking, very little advantage accrued beyond opening the eyes of the conductors to the necessity of having some more perfect medium for condensation, and turning the inflammable gases to useful purposes, as also for purifying the products, and bringing them into marketable condition. It was necessary, therefore, under these circumstances, to erect new works; and, as many things had to be invented, this occupied considerable time. The factory has now been in active operation for some few years. The arrangement for the combustion of the peat consists of four furnaces, constructed like ordinary blast furnaces, and without gratings, but furnished with three tuyeres through which the blast enters. Each furnace is thirty-two feet seven inches high, from the ground to the top of the hopper; the hearth is three feet two inches deep, three feet wide, and eighteen inches to the top of the dam-plate; the tymp is thirteen inches high, and has two inches of water space: the boshes are seven feet six inches high from the bottom of the crucible part, and twelve feet wide at the belly; the cone or body is sixteen feet high, and six feet wide at the tunnel head. The base of each furnace is square as high as the belly, and the whole of the cone or body is covered with boiler-plate firmly riveted. Such a protection is necessary, in order to prevent a leakage of the products of distillation, besides giving greater stability to the erection. The top of each furnace is completely closed by a conical valve three feet in diameter, and surmounted with a changing hopper provided with two tight-fitting lids. This hopper is five feet high from the valve-opening to the lid, and eight feet in diameter at the top. Two pipes, each twelve inches in diameter, convey the products of distillation into an hydraulic main, three feet in diameter, whence the condensed tar and other liquids flow into a tank, while the gases are made to pass through two double rows of upright condensing pipes, twelve inches in diameter, and twenty-five feet high, including two series of rectangular boxes upon which they are fixed. During the passage of the elastic vapors and gases through these pipes, an additional quantity of tar and aqueous products is liquefied and collected in rectangular boxes placed in connection with the pipes, by an arrangement which will be further explained in the drawings annexed. After the gases traverse the condensers, they are conducted through a series of eight scrubbers, twenty feet high, and arranged in four rows. Each scrubber has three layers of small stones resting upon gratings, and is besides furnished with a mill and tumbler, by which a dense shower is made to fall through the scrubber. By this contrivance the gases are washed of all traces of tar and condensable matters, such as naphtha, *et cetera*. From the

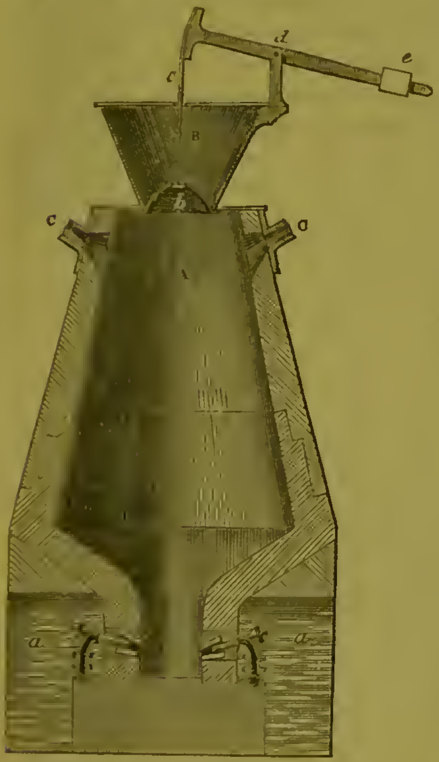
Fig. 40.



scrubbers the gas flows into a kind of main called the trunk, twenty-five feet three inches in length, and three feet eight inches in diameter, and from which it is distributed to the several fire-places to be consumed under evaporating pans or boilers, as required.

Fig. 40 is a side elevation of this arrangement, represented, for want of space, as broken off in the middle. A is one of the four furnaces, a section of which, along the line X, is shown in Fig. 41; and Fig. 42 is a plan of the platform, G, on the top of the furnaces, with part of the condensing apparatus attached. The same letters in each of the figures indicate corresponding parts.

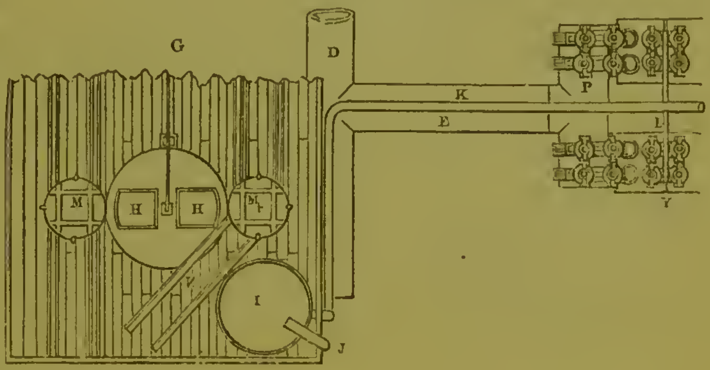
Fig. 41.



Referring, in the first place, to the sectional view of the furnace—Fig. 41—*a* represents the arrangement of the tuyeres, with their nozzles, showing the water spaces and the plug valves for allowing the tuyere opening to be kept clear; B is the hopper, which is provided with two lids, H H, Fig. 42, hinged and flanged, so as to fit into grooves; and *b* the conical valve with its ground rim, into which fits a circular flange surrounding the valve opening. The valve, *b*, may be raised or lowered by means of the rod and chain, *c*, attached to the lever, *d*, which is furnished at one end with a box, *e*, for the reception of pieces of cast-iron or other material to form the counterpoise.

The platform on the top of the four furnaces, part of which is represented at G, in Fig. 42, is constructed of planks of wood laid on the same plane as the covers of the hoppers. The dried peat or turf is elevated to this platform in iron waggons, each thirty cubic feet in capacity, by means of a water lift, consisting of a floor upon which four waggons fit, supported by a frame or cage with friction pulleys at the angles, for working against the four upright pillars of wood which support a framework at top, having a drum and brake. The flooring of the cage is attached to a chain which passes over the forementioned drum, and is counterpoised by a wrought-iron cistern, five feet square, and two feet six inches deep, provided with a valve in the bottom, with an externally projecting spindle. The peat is brought from the bog in flat-bottomed boats by the canal, which terminates in a kind of basin, having a quay a few yards wide at the foot of the lift. Here the waggons are filled with the turf, and they are then rolled in upon the floor of the cage previously let down to receive them. In this position of the cage, the counterpoise or cistern is at the top, and, while there, water is allowed to flow into it from the tank, I, which is in turn supplied by the feed-pipe, J, connected to a large pump worked by a steam-engine which drives the other smaller ones throughout the works. When the cistern is full, it more than counterbalances the weight of the cage and loaded waggons; and, accordingly, on letting go the brake, the former descends, and by means of the chain passing over the drum, draws up the cage and waggons to the level of the platform, G. When the cistern full of water reaches the ground, the projecting pin strikes against it, by which the valve is lifted, and the water allowed to flow out. The waggons full of turf are next rolled along tramways at each side of the hoppers, one of which is shown at N, to the furnace into which it is discharged. This part of the work is performed by rolling the waggon on to a turning table, M, situate at each side of the furnace, and there made to perform a fourth of a revolution, so as to bring the end of the waggon, which is provided with a hinge and latch, over one of the hopper lids, H; the latter is opened, and the turf discharged into the orifice. Three waggons full, or ninety cubic feet, fill the hopper, and this constitutes a charge. Whilst the hopper is being filled, the conical valve, *b*, is raised to the position in which it closes the furnace, as shown in Fig. 41, and none of the products of distillation can escape; but as soon as the hopper is filled, the lids, H H, are firmly closed, and the grooves into which the lid flanges are partly filled with turf dust and some of the blue clay marl underlying the peat bog, mixed up into a magma with water. This paste forms an excellent lute round the lid, which is kept tight by a latch.

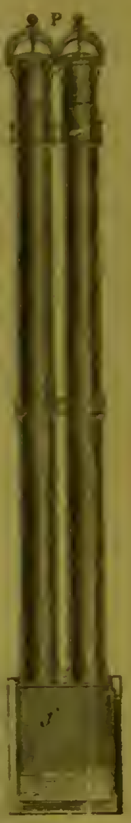
Fig. 42.



The valve, *b*, Fig. 41, may now be lowered by the lever, *d*, which, while the valve is up, has its extremity bearing the counterpoise, *e*, hooked to the platform by means of the small aperture seen near the counterpoise; but when this is unhooked, the valve descends, and the turf falls into the furnace. This being effected, the lever is again hooked in the usual position, and the hopper recharged. In this method of working, the only loss sustained is merely the full of the hopper of gases each time the furnace is charged. When light peat is burned, the charge weighs about seven hundredweight, so that it would require about a hundred and forty-three charges to burn fifty tons of material, and two hundred and eighty-six to burn one hundred tons, the work assigned to each furnace in twenty-four hours. Allowing one hundred cubic feet of gas to be lost at each charge, the total for each furnace during the day's working would amount to twenty-eight thousand six hundred cubic feet; but this is too high, for the average weight of a charge of the brown turf employed is about half a ton, and, therefore, only two hundred charges are required to perform the work, so that the loss is reduced in actual practice to twenty thousand cubic feet; and this quantity, compared to the total quantity produced, is very insignificant.

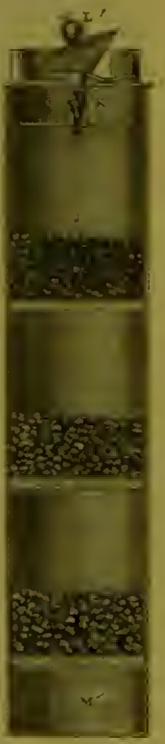
When the fire is lighted in the furnace, and the blast directed upon it, the part immediately ignited is resolved into the simplest and most permanent products of combustion; but as these ascend, the carbonic acid is resolved into carbonic oxide by the incandescent fuel overhead, and this gas, together with the nitrogen of the air, rises in a heated state through the mass. These superheated gases are the agents which effect the distillation of the great mass of peat in the body of the furnace, and carry the products off to the mains, as already intimated, by outlet pipes, C—Figs. 40 and 41—of which there are two to each furnace. These outlets are fixed near the top of the furnace; they consist of a short ascending and a long descending pipe, the angle where they meet being provided with a hand-hole for cleaning out, and which can be secured by a dog and screw. The long arm enters the hydraulic main, D, shown in section in Fig. 40, and represented as broken off in the plan, Fig. 42. This main is kept half full of liquid, below the surface of which the outlet pipes dip. Each furnace is thus isolated in the same way as the retorts in a gas factory. The hydraulic main consists, properly speaking, of two; the principal one running along the furnaces in front, and marked D; and, secondly, a cross piece, E, which connects the former to a shorter one, F. Both these are closed at the ends with plates of iron, which can be removed whenever they want cleaning. Overflow pipes, screwed to those plates, draw away all the tar and liquid which accumulate in the mains above the proper level; this excess is conveyed into a tank not marked on the drawings, but its place is indicated by Y, in Fig. 42. Four ascending pipes convey the gas from the main into the condensers; each of these pipes is provided with a valve, W. As was already stated, there are two distinct series of condensers, each consisting of eighteen rectangular boxes, shown in section at U, Fig. 43. Upon the top of each of these are placed four upright pipes, and those of each series constitute two rows. The adjoining pipes in each row, belonging to different boxes, are connected by a breeches-piece, which has two openings in the top, closed by caps, dogs, and screws, P. The gas flowing through the valve, W, is thus enabled to ascend one pipe in a row and down the next, into the first rectangular box, thence up the next, and, by means of the breeches-pipe, into the adjoining condenser pipe and box, and so on. A diaphragm, as seen in Fig. 43, separates the box into two compartments; this division is not perfect, however, for at the bottom a space is left, so that both form only one.

Fig. 43.



The four pipes open into one compartment, and as both are kept nearly half full of water, the gas entering into the side compartment cannot escape otherwise than by the pipes, unless the pressure is so very great as to force all the liquor out by V, into the next chamber. All the condensable matter that accumulates in the inner chamber soon finds its level in the outer one by the communication at the bottom of the box, and when it rises to a certain height in the latter, it flows out by a siphon pipe into a conduit in connection with the tank, Y. All the boxes are in communication with one another by a short connecting pipe passing from one to the other near the bottom; the same level of liquid is thus insured in all. To prevent the condensing pipes ever getting too hot, a conduit, K—Fig. 42—in connection with the cistern, I, is carried along the top between the two rows, to each set of which it sends out an arm, L, pierced with small holes, which allow a fine stream of water to fall on the tops of the pipes, and to trickle down the sides, and thus cool them effectually.

Fig. 44.



Notwithstanding all the refrigerating surface afforded by the double line of condensers, a certain quantity of tar and ammonia, and the greater part of the naphtha, still remain uncondensed, and are carried forward mechanically by the force of the blast; and to guard against a loss being sustained, the scrubbers, Q—Fig. 40—have been appended. These are arranged in four rows, corresponding to the four rows of condensing pipes. Each scrubber consists of a cylinder of wrought-iron, four feet six inches in diameter, and twenty feet high, closed at both ends, and having three gratings in the interior, upon each of which is placed a layer of stones, shown at *j*, Fig. 44. The gas enters at M′, and passes up through the layers of stones, while, at the same time, the mill, K′, supplied with water from an inch pipe connected with K, Fig. 42, or with the tumbler, L′, produces a dense rain by its revolution; and this shower meeting the gaseous bodies ascending through the layers of stones, completely removes all the considerable bodies remaining in it. The water which thus traverses the scrubber, and becomes partly saturated with tar, ammoniacal matter, and naphtha, flows off from the base by a pipe into a tank, not exhibited in the drawing, but which may be designated by Z, Fig. 40. After passing through the first scrubbers, the gas enters the second series by means of a pipe, and after it is washed in these, as described, it flows into a kind of gasometer, S, Fig. 40, consisting of a pipe twenty-five feet three inches long, and three feet eight inches wide, and kept full of water to the level of the line shown. By means of the valve, W, in the main, F, and the dip of the pipe, R, into the water of the gas-holder or trunk, S, each row of condensers, and each pair of scrubbers, may be isolated, and the gas shut off from them whenever they require cleaning.

As the whole of the water which passes through the scrubbers must be distilled in order to obtain the ammonia and naphtha which it has absorbed, it is found desirable to make the same liquid serve two or three times for washing the gas. This is done by placing barrels, T, on the tops of the scrubbers, Q Q, and pumping into them from time to time a portion of the liquor from the tank, Z. Each barrel supplies liquor to four scrubbers, by means of branching pipes.

Owing to the retention of the tar by the layer of stones, the scrubbers would get clogged from it, were there no provision made for cleansing them. The means adopted is to inject steam into them once in the day, by which the tar is melted, and in this state flows out at the bottom of the tank. From S the combustible gases are carried off by a duct, from which, by other channels, it is taken to the several flame-beds, where it is consumed.

Such are the principal details of this manufactory, having in view the recovery of the volatile products of distillation only, the charcoal which the peat would afford being entirely burned.

The high heating power of peat-charcoal, as well as its disinfecting and other qualities, invest it with peculiar interest to the smelter, the sanitary reformer, and the agriculturist: for the former it has long been productive of great advantages, more especially in the manufacture of iron, and therefore its production, on the most economical scale, and in the largest quantity, has been a subject to which some attention has been paid. This is more particularly the case in Bohemia, Bavaria, France, Russia, and other countries, where it is used in the blast-furnaces of their iron-smelting establishments, and produces very satisfactory results. In the numerous other processes to which the metal is subjected, the charcoal is found quite as efficient, if not more so, than wood-charcoal. In England, however, where coal is so abundant, a material which is at her command in as great abundance as her coal, has been allowed hitherto to remain useless; but it is to be hoped, that the success which has attended its application in the particular instances alluded to, and the free discussion of its advantages which one now meets with, will remove any prejudices existing in the minds of manufacturers against its employment. At present, or at least till within a recent period, the cost of the product has been very high, in fact out of all proportion when compared to that of other kinds of fuel; and this, perhaps, has been one cause why it has not been extensively consumed in smelting and other works: but if, by the attention of manufacturers, the charring of peat had been understood, and conducted on such a scale as would bring its marketable value on a footing with that of coke, there is little doubt of its very soon being introduced into several establishments from which it is at present excluded. When peat is acted upon by heat in close vessels, it yields a variable amount of charcoal, from twenty-five to forty per cent., according to its density and state of dryness; but, as it is rarely distilled in this way, the quantity obtained is from twenty-five to thirty per cent., and at best does not exceed thirty-five per cent. The methods followed for the charring of peat are, in some respects, similar to those already described as being pursued in carbonizing wood on the large scale; these are the meiler system, and that by the furnace. For operations by the first of these methods, the nature of the peat and the regular form of the sods or bricks offer advantages for constructing the heap more regularly, leaving less interstitial space than the logs of wood, and, being less combustible than the latter, the process does not exact that minute attention which the carbonization of wood requires. It is necessary that the peat should be thoroughly desiccated, otherwise the charring will proceed irregularly, and sometimes not at all. Large quantities of peat are carbonized in this way in the Vosges, in Bavaria, Saxony, and Bohemia. In these places, one or other of two forms of constructing the meiler is adopted—either the circular or bee-hive, so frequently resorted to in charring wood, or the rectangular one. At the Royal Iron Works of Weierhammer, in Bavaria, where the refining and puddling of iron has been carried on since 1838 by means of peat-charcoal, the peat is charred in the circular mound, prepared almost as in manufacturing wood-charcoal.

A level site being chosen, a stake or quandel is fixed in the middle of a circular space, and round it on the ground a quantity of brushwood is spread, and which in turn is covered with waste charcoal from a previous operation. The turf is then piled round to the extent of the base, and to the proper height, preserving the conical shape. Generally, the size of the heap is about two thousand five hundred cubic feet, or thirteen and a half tons of the peat of the locality. When the central stake is withdrawn, brushwood is introduced into the opening and ignited. This communicates fire to the surrounding mass, which, in turn, conveys the heat towards the exterior. Owing to the closeness with which the turf admits of being packed together, the carbonization would proceed but slowly, were it not that air-channels of the breadth of a single brick of the peat are constructed at regular distances, and radiating to the circumference of the meiler. A covering of moss and leaves is placed upon the body of the heap, and outside this another of sand and turf ashes, or charcoal dust, is thrown on, leaving the upper part open, as a kind of chimney for the passage of the gaseous products, till the mass has been thoroughly ignited. As soon as flame appears at the top of the heap, a covering is thrown on, and the contraction of the mass observed, so as to keep any breaks occasioned by the sinking renovated. The charring is conducted regularly in the whole meiler by closing the draught-holes at the base, where the combustion becomes too vivid, or boring a few about a foot asunder in the upper part, where the progress is slack. Twelve to fourteen days are necessary to char and cool a meiler of the above size, so as to be fit for removal. About seven hundred cubic feet of charcoal are obtained, weighing about three tons eight hundredweight, or 27·7 per cent.; hence, somewhat less than four tons of the peat of the district yields one ton of charcoal.

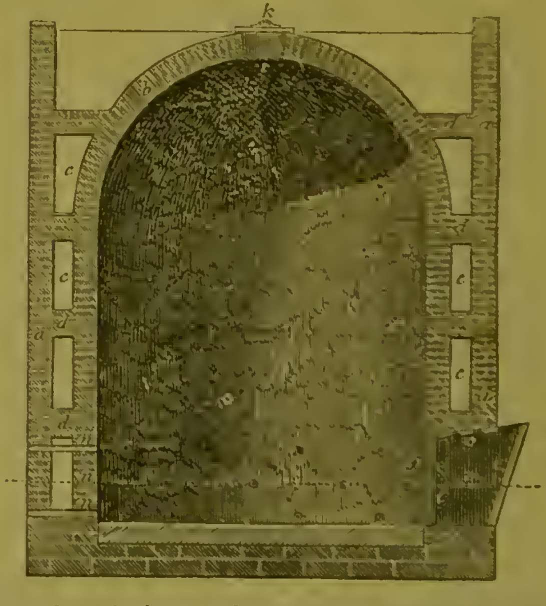
In Saxony, the rick or rectangular system is adopted, and the results are good. The ground is levelled and covered with sand in the usual way, and afterwards the rectangular space marked out; this is about fifty feet long by five or six in breadth. The middle of this plot is hollowed out into a kind of basin, and from it two channels or drains are cut from the ends of the intended heap, but inclining towards the central cavity. Both channels and well are constructed of, or are lined with bricks, a layer of clay being laid beneath, so as to prevent any fluid products collecting therein from percolating through the soil. A small gutter leads from the cavity in the middle to a tank at a little distance, where the liquids are recovered. These necessary constructions being made, a number of quandels is fixed in the longitudinal channel, ten feet apart, and the peat heap constructed to the height of four feet, leaving transverse channels corresponding with the vertical one which the stake forms. When finished, the quandels are withdrawn, and the whole coated with a mixture of clay, sand, and chopped straw or grass, the latter being used to prevent the luting from cracking. This mixture is prepared in two boxes or pits, one at each side of the mound, and quantities of it are always at hand so as to be available for stopping any cracks which might present themselves during the charring. Ignition is commenced at each end of the rhomboid by a fire placed in the central channel; the brushwood with which this has been filled burns, and, in doing so, sets fire to the surrounding peat. When the turf is fully ignited throughout the whole mass, a thick black smoke issues from the chimneys; as the carbonization proceeds, this becomes lighter, assuming gradually a greyish-white color, and finally changes to a bluish shade as the moisture evaporates. At this state, sulphurous acid becomes disengaged. As soon as the whole of the moisture is dispelled—a fact ascertained by holding the hand in the vapor as it issues from the chimneys, and observing if condensation takes place—the fire is gradually smothered by closing the air channels and fire flues. Care is also required in the management of the draught, so as not to allow of a consumption of charcoal taking place; generally, the apertures on the windward side are kept closed, the opposite ones being sufficient to supply air. The charcoal prepared in this way is of excellent quality, and much used in the metallurgical establishments of Saxony and Bohemia.

Both these systems of charring peat afford nearly the same yield of charcoal, when the operations have been properly attended to. It ranges from twenty-four per cent. by weight and twenty-seven by bulk when the peat is not thoroughly air-dried; but if this condition has been attained, the product is about twenty-seven per cent. by weight, or thirty-two and a half by bulk: a larger produce is occasionally obtained, but in those cases the exception must be attributed to the density and dryness of the material before carbonization. The cost of a ton of charcoal at Weierhammer, manufactured by the process described, is about sixteen shillings and twopence, the peat from which it is produced having a marketable value of two shillings and elevenpence halfpenny per ton: allowing that four tons of peat are required for the production of one ton of charcoal, it appears that the charring expenses for one ton of charcoal are about four shillings and fourpence. In the neighborhood of Carolinen Hütte, near Achthal, in Styria, where some successful attempts have been made to smelt iron with peat in its raw state, mixed with wood, a ton of peat-charcoal costs twenty-two shillings and sixpence; but of this, eighteen shillings and twopence form the cost of the material, so that, practically, the charring expenses are the same as at Weierhammer. Such is also the cost of carbonizing by the meiler or rick system in Saxony.

Partly from the fact that less labor is required in managing the operation, whilst a regularity in the produce is, in some measure, insured, and partly from the circumstance that there always exists a supply of material at hand in every peat district, which would render the expense of removal of furnaces unnecessary when once erected, the system of charring in kilns has been resorted to with advantage. Furnaces or kilns are employed near Meaux in France, in East Friesland, and Bohemia, to a considerable extent.

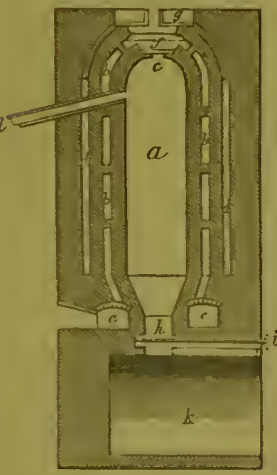
The furnace or kiln employed for this purpose at Oberndorf, in Wurtemberg, is represented in Fig. 45. It is an upright cylinder, nine feet high and five and a half feet in diameter, having a capacity of about two hundred cubic feet, and capable of distilling about four tons of average peat; the top is closed by an arch, with the exception of an opening, *i*, through which the peat is introduced; it also answers the purposes of a chimney till the charge is carbonized. A double line of construction is adopted in the erection of these kilns; an inner one, *b b*, of firebrick, and an outer one, *a a*, of more common material: both are about fifteen inches thick, and between them is an interstice, *c c*, of the same width, excepting where the brickwork extends the

Fig. 45.



whole breadth, as at *d d*, for giving greater firmness to the construction. The superior aperture, *i*, is closed by a tightly-fitting lid, *k*, when necessary; at the base is another door, closed by a cast-iron plate, *f;* and behind this is a space, *m*, formed by the door and the plate or board, *e*, and which is filled with sand through the aperture, *g*; thus the draught is effectually cut off at this orifice. There are three tiers of holes, *d d d*, formed at a short distance from the base of the furnace, through which air enters for supporting the combustion of the peat during the carbonization, as long as this takes place. In working this kiln, the peat is thrown in at the top and packed closely, with the exception of a few channels left free, corresponding to the lower draught holes, and also a vacant space in the centre; after being filled, fire is thrown in from the top, and the orifice in this part left open; when the fire has spread through the mass, so as to present a glowing appearance on being viewed through the lower apertures, these are closed with clay stoppers, and the combustion allowed to proceed till the same appearance is observed on looking through the second holes, when these are likewise stopped; and when the mass appears white hot at the third row of perforations, and no more smoke appears, all the apertures are secured, and the mass is allowed to remain till cold. Forty-eight hours are occupied in bringing the mass to incandescence, and after that seven or eight days are required for the cooling of the furnace. To avoid this delay, it is customary to have a damper plate situated in the bottom of the furnace, under which is a pit, so that, on withdrawing the damper, the red-hot charcoal falls into the pit, and the furnace is ready for a fresh charge. Sometimes the furnace is so constructed as to enable the manufacturer to recover some of the products of distillation, and use the combustible products for heating the mass of peat. In these, a pipe leads from the shoulder of the arch to a kind of condenser, where the ammoniacal and tarry matters are retained, and the gaseous bodies are reconducted by pipes to the bottom of the furnace, where they are burned under a grating, and serve to ignite the charge. No delay, or at most only an inconsiderable one, takes place in the charring with the latter kind of furnace, and the product is satisfactory in relation to quality and yield.

Fig. 46.



Of this description are the kilns used at Crouy-sur-l'Ourcq, near Meaux, one of which is represented in Fig. 46. In this kiln the carbonization is effected in a cylinder, *a*, heated exteriorly by the flame and heat from the fires, *c c*, which circulate in the spiral flue, *b b*; *d d* is a chamber, encircling the walls of the flue, wherein air is confined, with the view of retaining and equalizing the heat. The peat is introduced into the kiln by the aperture, *e*, at the top, this aperture is closed when the charring is going on, by an iron plate, *f;* the products of the combustion going on in the fires, *c c*, issue by an opening, *g*, in the top, and those of the distillation of the charge by a pipe, *l*, connected with a condensing apparatus of the usual construction, and in which the liquid products are retained, the uncondensed gas being conveyed back to the fires, where by their combustion they serve, in part, to maintain the proper degree of heat. When the carbonization is completed, the charcoal is removed by the channel, *h*, by drawing the plate, *i*, which serves as the bottom of the kilns; it then falls into the chamber, where it is allowed to cool; from thirty-five to forty per cent. of charcoal is obtained, according to the density and state of dryness of the crude fuel. The cost of charring by this furnace is estimated at an average of four shillings per ton of charcoal.

Somewhat differing from the latter in construction, though worked upon the same principle, is the peat-charcoal furnace of East Friesland. It has a solid base sixteen feet long, thirteen wide, and two feet thick; upon this base an oblong furnace is erected, twelve feet long, five wide, and eight and a half high. The end walls of this construction are two feet thick, but the sides are only six inches; parallel with the side walls, and at a distance of eighteen inches, two others are built, each two feet thick, and the end ones are continued at both sides to meet them. By this arrangement a space is enclosed between the interior construction, or the retort, and the exterior wall, and this space serves for the fire channel, in which the products of combustion, from a fire lighted in a hearth, one foot high and eighteen inches wide, with grate and ashpit, made at one end of each of these chambers, circulate for the purpose of heating the retort. An arch or dome completely encloses the inner chamber destined to carbonize the peat; another similar arch is sprung from the outer walls, thus encasing the top of the retort as well as the sides. At the end where the fires are situated, a charging door, five feet high and three wide, is situated, and this, when the process of charring is going on, is kept tightly closed. The floor of the inner retort is hollowed in the middle along the whole length, and the channel thus formed walled by a glazed clay gutter, and covered over with perforated tiles, the whole slightly inclined towards one end. The tar and other fluids which accumulate here during the carbonization, are carried off by a pipe to a tank at a short distance from the retort, and the uncondensable gases conducted back by other pipes to the furnace, where they are burned. For the sake of economy, two or more of such furnaces are built close to each other, by which the time of charring is shortened, less heat being allowed to escape. Such a furnace is capable of producing one ton of charcoal at each operation, at an average expense of four to five shillings.

Another furnace employed in Bohemia is the following:—A circular excavation six feet deep and twenty in diameter, is made, and the base lined with brickwork nine inches deep. Upon this the walls of the furnace are constructed, so that when completed the whole forms a frustrum of a cone. For this end, the walls are five feet thick at the base, and tapering, till, at the height of sixteen feet, that of the furnace, they are only two, thus leaving a cylindrical space of ten feet in diameter for the charring. At the top or mouth an arch is sprung, and covers the whole in the form of a dome; in the centre of this is left an opening three feet in exterior, and two in interior diameter, and closed by a door, when necessary, with four others at regular distances in the shoulder of the arch. The opening at the base for withdrawing the made charcoal is four and a half feet high, and two and a half wide; this is closed with bricks, and the opening from without secured with boards, so as to keep in the heat as much as possible. A canal is formed round by the base of the wall of the furnace in the interior, nine inches wide and fifteen deep, and two others of the same dimensions intersecting the preceding, one of which opens under the discharging door. Before the charging commences, these channels are filled with brushwood, and partially covered with tiles placed a few inches apart. Before introducing the peat, a pole is fixed in the central opening, and likewise one in each of the others, the lower ends of these filling in the intersections of the circular and cross channels; the charging is then proceeded with, the peat bricks being as nearly as possible placed endwise. When filled, the poles are withdrawn, leaving five vertical flues in their stead. The brushwood in the channel under the discharging door is then ignited, and the fire spreads quickly round the base and across it, so that the heat is equally exerted upon the whole of the peat in this part. All the apertures are left open till a volume of flame freely issues from the orifices in the dome; the charging door is then closed, and further secured by luting or sand being spread over it; the firing flue at the base is likewise secured tightly. The other openings in the dome are only slightly covered, so as to allow the escape of the products of distillation. When the latter cease to be evolved, the openings are entirely covered, and the furnace left to cool for forty-eight hours. In many operations, preference is given to the charcoal manufactured in this furnace, over that prepared in the kilns used at Crouy-sur-l'Ourcq.

A few years ago Mr. J. W. ROGERS introduced a furnace for the carbonization of peat, as well as for drying it previous to its being carbonized. Fig. 47 represents a longitudinal section, and Fig. 48 an end view of this ingenious construction. E E is a boarded shed supported on pillars, and open in a great measure at the sides. In the middle of the flooring of this structure a channel is sunk, which constitutes the ash-pit; on each side of this channel a line of rails is laid, forming a railway, on which the carbonizing chambers or kilns, A A A, furnished with small wheels for the purpose, move. The furnaces are of sheet-iron, upon a framework of the same metal, the whole forming a truncated pyramidal case, of which the base is a grating upon which the peat to be charred rests. These cases are filled by inverting them and introducing the peat, the grate being removed; the latter is then replaced, and after restoring them to their original position, they are rolled along the tramway over the ashpit. The space through which the ovens pass is encased with sheet-iron, B B, through which, at regular intervals corresponding to the position of the furnaces, pipes, D, D, lead to the top of the building. Within the latter, other movable ones are placed, which fit upon the orifice of the kilns when fixed in the shed; these constitute the chimneys, and they can be raised when it is required to draw out the case from under them. The space between the carbonizers and the roofing of the shed is fitted with shelves for the reception of the air-dried peat, for the purpose of desiccating it more completely. As the exterior covering is formed of a number of movable louvres, H, H, they may be opened or closed at will. The draught in the chamber of the furnaces is regulated by the flue door, *d*, worked by the rod, *e*. When the charring is commenced, some brushwood is introduced into the channel, over which the furnaces are rolled and ignited; the flame lights the peat, and the work proceeds till the contents are carbonized. This is known by no more smoke being given off; the chimnies are then closed by the flue doors, *d d*, and the furnaces and contents removed. The heat radiated from the sheet-iron plates serves to dry the peat stored on the surrounding shelves. Each of these furnaces carbonizes a charge of about six hundred pounds in five hours, and which yields a result of about twenty-three to twenty-five per cent. of charcoal. Four of these furnaces produce one ton of charcoal in twenty-four hours, and the cost of production, notwithstanding that the raw material would be purchased for two shillings per ton—that is, eight shillings for raw material—has been estimated at twenty-five to thirty shillings; by this the expenses of charring would

Fig. 47.

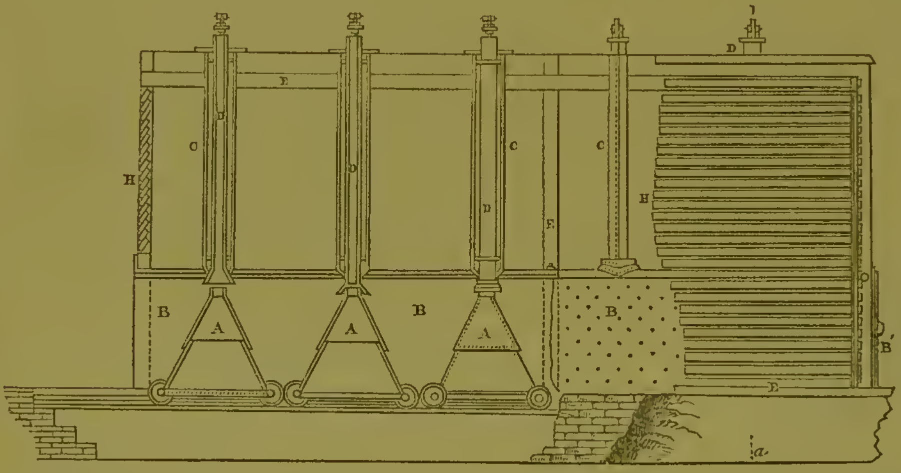
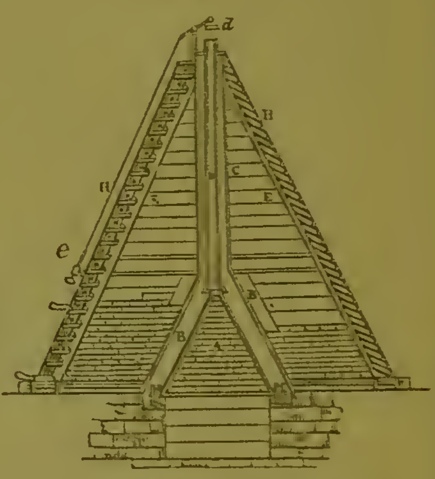


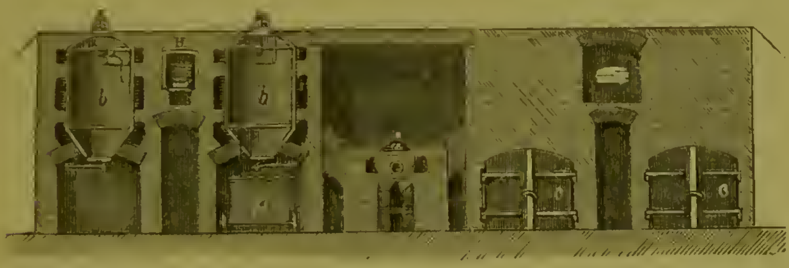
Fig. 48.



equal from seventeen to twenty-two shillings per ton. To prepare the peat, the patentee piles it, after being cut, upon wicker hurdles, one above another, and allows it to remain in this state till dry. The yield of charcoal is stated as from thirty-three to thirty-six per cent. —*Journal of Industrial Progress.*

VIGNOLES has taken out a patent for drying, compressing, and carbonizing peat, the latter being effected by means of steam heated to 450° or 460° Fahr., and the two former by a hydro-extractor, in which the centifrugal force expels the water, and renders the mass denser at the same time. With reference to the charring—the peat dried in the air, or by a current of heated gases forced through a chamber containing it, is thrown into cylindrical vessels, into which steam at a high temperature is forced, till the charring is effected. Fig. 49 shows a vertical section and partial elevation of the apparatus. In this, *a* represents a section of the boiler employed for raising the steam; it is placed over a furnace, the flues of which, after passing under the boiler, branch off and circulate round the carbonizing cylinders, and finally enter the chimney. Two of the charring cylinders are shown at *b b*, of which there are six at each side of the boiler; they are ranged round a coil of piping, H, in which the steam from the boiler is heated to the required degree by a fire, previous to its passing into the cylinders where the peat is charred, by means of pipes connecting them. After the steam traverses one of these carbonizers, it escapes by a pipe, which conducts it over the furnace, to raise its temperature previous to its passage through the next carbonizer in the series. In this way, the steam being first heated, is made to traverse a carbonizing vessel and the heating pipe successively, till it passes through the whole of the charring vessels. Ultimately, the waste steam is made to work a low-pressure engine, which turns a fan that forces air, heated by pipes placed in a furnace to 250°, into the drying chamber where the peat is desiccated.

Fig. 49.



The carbonizers, as may be inferred from the drawing, are conical towards the bottom, and are furnished with a valve or door which is rendered steam-tight, but may be opened when the charring is completed, so as to allow the charcoal to fall into a box, *p*, beneath it, and into which low pressure steam is passed for the purpose of cooling the charcoal. These boxes are constructed of iron, and are well covered, lest the charcoal might spontaneously ignite, to which it is liable, if exposed to air at this temperature; they move on tramways, and can be drawn out when required through the door-ways, *c c*. The top of the cylinder has a similar opening secured by a screw; through this aperture the charge of peat is introduced.

Several other patents have, within the last few years, been secured by parties for economizing fuel, but to dwell further upon them would be out of place, as many of them come within the range of processes for the manufacture of artificial fuel, more than for preparing the peat alone in an improved state. That of Mr. P. M. CRANE, from its simplicity and its connection with the process already detailed, as pursued by the Irish Peat Company, will be briefly explained. The improvement to be noticed in this patent is the annexing of another furnace to that in which the combustion of the peat was effected in the above-mentioned Company's works. In this appended furnace, the peat is consumed by a blast of air in the ordinary way, and the torrefied gases are conducted by a flue to the second one, which is likewise filled with peat, and the heat thus communicated chars the matter. In this way charcoal may be prepared without any loss of the products of distillation, as both furnaces may be closed down in the manner described in Fig. 41. The appended hearth or furnace may be modified, so as to enable the manufacturer to burn coal or coke, or even the waste gases formed in the distillation of the peat, turning the caloric and heated products which they yield to the use mentioned.

Fig. 52 is a sectional drawing of one of CRANE's furnaces for preparing charcoal by the combustion of peat alone. In this drawing, A B is the furnace connected with another furnace or charring chamber, C D, by a flue, G. Both these are filled with peat, and closed down in the manner described at Vol. II., page 60. The furnace, A B, is lighted, and the blast of air thrown upon the ignited fuel through three tuyeres, *c c c*, at the bottom. The heated gases are forced over into the furnace, C D, and passing up through the peat, char it. All the products—as well those from the combustion as from the charring furnace—are carried off by the exit pipes, F F, to the mains and condensers in the usual manner. When the peat in the charring furnace becomes carbonized, the charcoal is drawn out at E, into covered tanks, or cast-iron boxes, in which it is allowed to cool out of contact with air. According as the peat becomes consumed in the first, or the

Fig. 50.

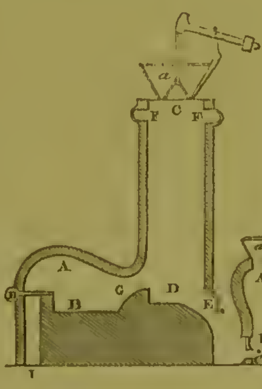


Fig. 51.

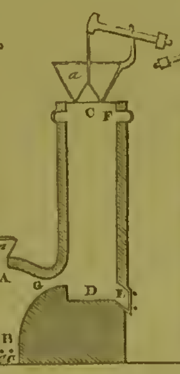
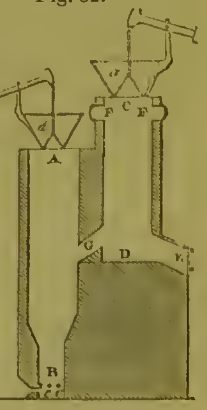


Fig. 52.



charcoal is withdrawn from the second furnace, the space rendered vacant is filled by charging the hoppers, *a a′*, and letting this charge into the furnaces in the usual way. Figs. 50 and 51 show the construction of the furnaces intended to consume coal, or anthracite, and gas, for the purpose of generating heated products for distilling peat. Fig. 51, for coal, needs no explanation, as its operations are similar to the foregoing. When gas is employed, it is conducted to the hearth, A B, by the flue, I, Fig. 50, and, being ignited, a blast of air is introduced by pipes communicating with a blast-pipe, H. The pressure of this blast forces the heated products through the carbonizer, C D, producing the intended results.

Such are the methods in common use where the preparation of peat-charcoal has been industriously pursued, and some of them offer considerable advantages. Of the analyses of peat-charcoal little need be said here, as the analyses of peat already given will throw some light upon this part of the subject. As a generator of heat, good peat-charcoal is as efficient as bituminous coal; and some varieties are even above the average heating power of the latter kinds of fuel.

COAL.—This is by far the most valuable and extensively disseminated fuel, or source of heat, and is defined by REDFERN—*a compressed and chemically altered vegetal matter, associated with more or less earthy substances, and capable of being used as fuel.* This definition expresses all that is necessary; but its truth can only be established by the concurrence and aid of several branches of knowledge. For instance, *animal* matters may, by a process of decomposition, yield a mass of carbonaceous substances, which could not be distinguished from similar vegetal ones by the naked eye. In such cases, the microscope and chemical analysis lead to a certainty as to the nature of the originals; the former by revealing the texture of the fibrous matter of the plant, and the latter by the separation and estimation of those bodies into which it has been partly resolved. Before giving any detailed account of the process by which coal has been produced, it may be well to explain briefly the proofs which are cited in argument to show what coal is; and for much of what follows on this point, the Editor must acknowledge himself indebted to the treatise on *Fuel and its Applications*, by RICHARDSON and RONALDS.

Evidences of the origin and character of coal may be gathered from the geological position of the deposit, the mineral characteristics, the chemical nature, and the visual appearance of the substance under high magnifying power. It is the opinion of geologists that coal may be viewed as a stratified rock, in which layers of other geological formations—such as clays, sandstones, and limestones—are found. These, in themselves, form vast deposits, or strata; but, in this respect, there is no difference between them and the coal-beds, excepting in the nature of the substances. How the matter has become so stratified, is a question to be afterwards considered. The coal seams vary from a mere film, or a layer of less than a quarter of an inch in thickness, to three or four feet. It is not often, however, that the deposits are of the latter dimension. In mines, where the depth of the carbonaceous deposit averages from ten to twenty or thirty feet, seams of mineral matter interpose themselves at intervals, varying as to the distance between them, but rarely exceeding the limits above assigned. All coal-beds contain these foreign strata, or *partings*, to a greater or less extent; they seem to have been the result of the precipitation of matters held mechanically suspended in water. The thickness of these intervening deposits is found to vary considerably from a mere seam to a bed of several feet. In many cases the mineral matter, thus interstratified, has become so saturated with bodies emanating from the coal, or during its formation blending with the carbon, that it ignites and burns like coal, only that its bulk of earthy substances remains, often retaining the original form. Such matters are frequently observed in the burning of many varieties of coal, and in common language are called *slates*, *batts*, or *basses*. This blending of the two substances is often so unmistakable, that at a glance it may be ascertained whether the *shale*, as it is called, is argillaceous or calcareous; but when it is known that the coal-beds belong to the alluvial deposits, it will be evident that the intermixture of mineral and organic matters must have proceeded collaterally, even although the latter appears in such excess as completely to obliterate any traces of the former. In Great Britain, coal is principally in the carboniferous formations, occupying a posterior place in the series of stratified rocks; and where the same stratification of limestone rocks is met with in other countries, beds of coal are generally to be encountered. Still coal is not confined to this set of rocks; it is found in different parts of the strata, from the Devonian down to the most recent tertiary formations.

Mineralogical Characters.—Although here the subject under consideration is spoken of as a mineral, it ought to be remembered that, strictly speaking, it is not a pure one, but a mixture of various matters, of which carbon is the principal. It may, however, be regarded as organic matter *mineralized*; and, as it manifests some of the general properties of minerals, these will be noticed. The several known varieties of coal possess each some distinctive feature, differing from one another in hardness, fracture, *et cetera*. Several species break up into cubical and rhomboidal fragments; whilst others—such as the anthracite—are nearly devoid of crystalline structure. Generally, the fracture is conchoidal, uneven, fibrous, or slaty; in Boghead coal the fracture is conchoidal, perpendicular to the plane of stratification, but slaty when parallel. In color, it presents according to the variety every difference of hue, from jet-black to brownish-yellow; many kinds have a glossy brilliancy; others—such as the varieties of anthracites—a beautiful semi-metallic iridescent lustre; whilst some—such as the Wemyss, Methil, and other varieties of cannels—have a dull appearance. Coal exhibits great differences in point of hardness, although none of the varieties possesses it in an eminent degree. Anthracite has a specific hardness of two to two and a half. The gravity of several kinds of coal differs according to the texture and age; the lightest kinds have a density bordering on 1·00, whilst the heaviest range from 1·75 to 2·00.

Chemical Characteristics.—From what has been stated, it is evident that a chemical examination of coal would, in the simplest manner, lead to its division into inorganic and organic substances, and that these are contained in it in variable proportions: and, further, that each of these classes can be resolved into other substances, the most characteristic of coal being those generated by the vegetal portion. This arises from the large proportion of the elements always found in it—namely, carbon, hydrogen, and oxygen; and which, by the action of heat out of contact with air, are converted into numerous and peculiar substances.

Distillation in close vessels resolves coal into solids, liquids, and gaseous bodies, consisting of carbon or coke, tar, ammoniacal liquor, benzol, naphtha, naphthalin, paraffin, paraffin oil, and illuminating and other gases, in various quantities. By the detection of these, and the proportion in which some are contained in the substance, a good inference may be drawn as to whether the body be coal or otherwise: nevertheless, the evidence is not so conclusive as when the investigation is conducted microscopically.

Microscopic Characters.—By the use of the microscope, the most conclusive proof of the origin of the coal is attained. Dr. AITKEN of Glasgow has carefully investigated the structure of coal, and found that, even in the most altered specimens, traces remain sufficiently characteristic to prove that the material is of vegetal origin.

In the variety of bitumens, whether pure mineral tar, or asphaltum, no such structure is observable, and consequently, in the hands of a chemico-microscopist there is nothing to render the detection of real coal a matter of uncertainty.

Origin of Coal.—Such being the principal or more marked characters by which a substance submitted to examination may be affirmed to be *coal*, it will now be desirable to enter more fully upon the origin and nature of this product, in reference to its value as a fuel. Allusion has already been made to the analogy which exists between peat and coal, and the reader will have inferred that coal, like peat, has been produced by the decomposition of species of organic growth. All who have given attention to the composition of coal, and the geological position it occupies, concur in this view of the subject; and the Editor will now explain briefly the different opinions advanced as to the manner in which the change and disintegration of the vegetal products have been produced.

It may be said that the process which has operated to convert countless reproductions of plants into peat bogs, has been similar in the case of coals to some extent; but, geologically considered, it is evident that the oldest peat deposits are of modern formation, when compared to the most recent beds of coal. Of the vegetal origin of the latter, no doubt can be entertained, even if the microscope had not revealed the fact in the more compact varieties, since among other indications, even the trees have been found in their natural position converted into coal. The character, the variety, and the immense mass of vegetal matter thus converted, have led to the conclusion that the several species of plants whence coal has resulted were indigenous to a southern or equatorial climate, as it is certain they could not flourish so luxuriantly in the existing temperature of northern latitudes. The varieties most commonly distinguished in the different strata are ferns, calamites, sigillariæ, stigmariæ, and others; in fact, no less than three hundred distinct kinds have been detected.

As to the manner, however, in which the strata of the coal deposits have been formed, there is much difference of opinion. Some geologists suppose that they were originally peat, the several successive layers being occasioned by successive subsidences of the land; whilst others assert that the various constituents were originally conveyed by currents to estuaries and deltas, where, being buried under the sand, mud, and debris brought down by the current, they were subsequently submitted to agencies which effected their carbonization. It is certain that the surface of the globe was at one time nearly submerged in an ocean, in which state it remained till, by the effects of volcanic eruptions, portions were uplifted, causing a corresponding depression in other places, and thus forming valleys, the forests and vegetation of which were buried under layers of loose earth and mud. At the same time, it would require many such forests to constitute a layer of the thickness of some of the coal seams, and these can scarcely be imagined to have been produced otherwise than by the drifting of vast accumulations of trees and plants into the basins in which coal is now found.

But leaving geologists to discuss and settle these questions, it is more in accordance with the plan of this work to attend to the chemical changes which have contributed to the conversion of the organic fibre into the carbonaceous matter in question. Whether the organic products on the surface of the earth were collected by changes in the relative position of the earth's solid crust, or by the force of violent currents, such as the large American rivers of the present day, it may be admitted and assumed as a fact that they were embedded with other matters saturated with moisture. The first natural change under such circumstances would be a fermentation of the albuminous matter and the gum, by which their molecular constitution would be broken up, and bodies of a simpler composition formed. The exclusion of the air after a short time would suppress the eremacausis or decay of the substance of the wood and fibrous matter, but the equilibrium of the affinities of the elements in the plants being broken, and considerable pressure being exerted, coupled with a certain rise of temperature, the change of elements arising from the new elective affinities would contribute to remove the hydrogen and oxygen to that extent which is observed in the composition of coal. The oxygen and hydrogen being most subject to the effect of this metamorphosis, these elements, leaving the carbon, would more readily assume their simplest and most permanent state of combination; but, as in the process of destructive distillation already alluded to, the conditions supplied are capable of inducing the water thus constituted to react upon a portion of the carbon, so in the coal formations, where the enormous pressure must have operated with an effect in some degree equivalent to an increased temperature, the moisture and excess of hydrogen would convert the remaining substance into carbonic acid and carbides of hydrogen respectively. The actual facts, as determined in coal mines, seem to bear out this view.

From such considerations it will be readily concluded that the elementary composition of coals must be different from ligneous fibre; but following up the assumed alteration by a symbolical representation, the composition of coal offers very conclusive grounds to warrant the opinion that the former has resulted from the latter in the manner indicated. For instance, the composition of woody fibre may, as already stated, be represented by the equation $C_{36}\ H_{22}\ O_{22}$; and if, by the change above indicated, three equivalents of carbonic acid be extracted, represented by $C_3\ O_6$, there results $C_{33}\ H_{22}\ O_{16}$; and if from this one equivalent of hydrogen be taken away, represented by H, there is left a formula—$C_{33}\ H_{21}\ O_{16}$—corresponding with the composition of a variety of coal worked in Laubach.

In like manner the formula of splint coal may be deduced from the elements representing woody fibre, by supposing that the combined agency of heat and pressure removed nine equivalents of carbonic acid, three equivalents of water, and three of carbide of hydrogen, thus :—

1 Eq. of woody fibre,	=	$C_{36}\ H_{22}\ O_{22}$
9 Eqs. of carbonic acid,	=	$C_9\ ..\ O_{18}$
		$C_{27}\ H_{22}\ O_4$
3 Eqs. of water,	=	$..\ H_3\ O_3$
		$C_{27}\ H_{19}\ O$
3 Eqs. of carbide of hydrogen, ...		$C_3\ H_6\ ..$
Splint coal, ...		$C_{24}\ H_{13}\ O$

According to the degree of force exerted upon the decomposing substance, and the period of time in which this change was taking place, it is evident that the substances would be more or less removed from one another in composition. In the first example stated above, the formation bears every indication of recent production, when compared with the second; and this accounts for the close analogy between the two formulæ of wood and that species of coal. In other kinds, such as many of the anthracites, the alteration is much greater than even in the splint already referred to, and it is much more difficult to recognize the analogy between them and wood, for often all the oxygen and hydrogen are removed, so that nothing is left but carbon and the mineral matters intermixed with it.

Coal Measures.—The region of the coal formations is very extensive, and includes many strata, all of which are known as the *coal-measures*, or carboniferous group. Properly speaking the first of these is what is termed the *under-lay*; this is, a tough argillaceous substance, which, upon drying, turns grey and becomes friable. It retains considerable traces of carbonaceous matter. Two other strata beneath this are, however, included in the group; these are the mountain limestone, which varies very much in thickness, being sometimes nine hundred feet, and the old red sandstone upon which it rests; the latter stratum ranges from two hundred to two thousand feet in thickness. Next to the underlay in the ascending scale comes the seam of coal, or modified organic matter, varying from less than a quarter of an inch to several feet. Above these the upper layer or roof, as it is termed, rests. It is composed of slaty clay abounding in vegetal remains, as well as with crustaceæ, and several other matters. Interstratified with the latter are found various other substances, which seem to have been accumulations drifted by currents, such as laminated clay, grit, limestone, granite, sandstone, and other rocks.

All these deposits at one time, doubtless, formed regular horizontal layers, but through the effects of expansion in the depths of the earth, they have been distorted and thrown into undulated positions, and where the internal force has been very great, they have, by the upheaval of the subordinate strata, been formed into large valleys or basins. From the position of these layers, previous to such convulsions occurring, it is obvious that as the older deposits of mountain limestone, old red sandstone, *et cetera*, emerged in succession, so the more modern layers, including the carboniferous, would appear at the surface. This appearance is termed the cropping out of the strata, and serves to indicate the side of the basin. Considerable irregularity is occasioned by further subterranean disturbances which tend to alter the position of the strata subsequently to the first upheaval of the older formations. These generally render the deposits somewhat irregular in shape, so that they seldom form a true basin. In some localities, as in the Leicester and Warwickshire coal-field, none of the characters of a basin are observed; in the latter instance, the seams are surrounded on all sides by overlying deposits, under which they dip or incline to a considerable depth, and extend to an area unknown.

Fig. 53 represents this field in section, showing the alluvial deposits at A A; the new red sandstone, or marls, at B B; the carboniferous shale and coal at C C, interlaid with carboniferous grit, or sandstones, D D; E, beds of magnesian; and F the stratum of mountain limestone, resting on the old red sandstone, G. Fig. 54 gives a faint idea of the disturbances which are occasioned in the various beds by fissures filled with other materials. These veins are, in the language of the miner, called *dykes*, as they are the means of separating the strata

Fig. 53.

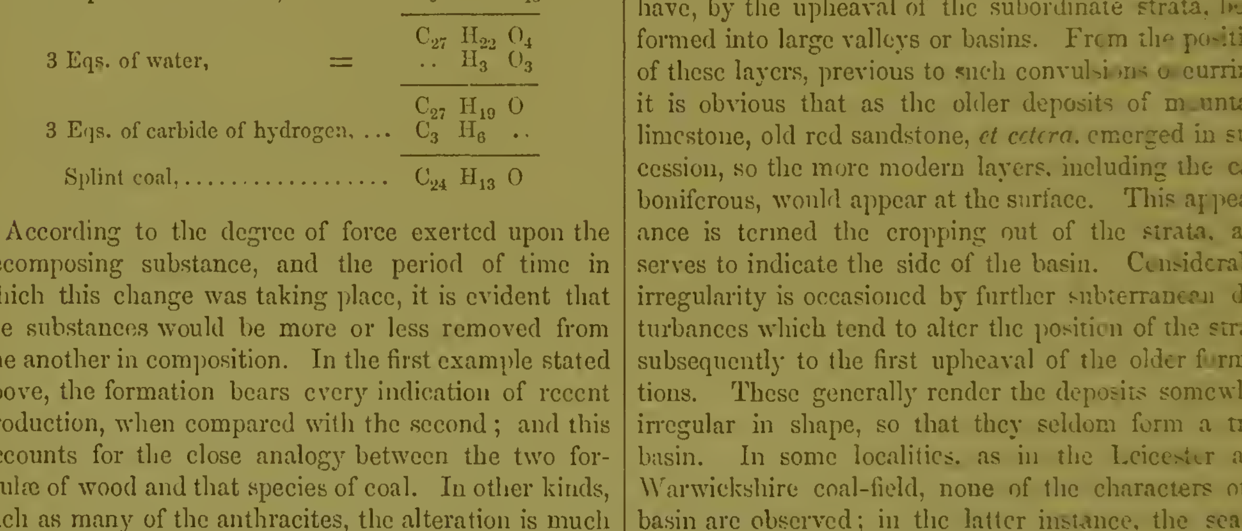
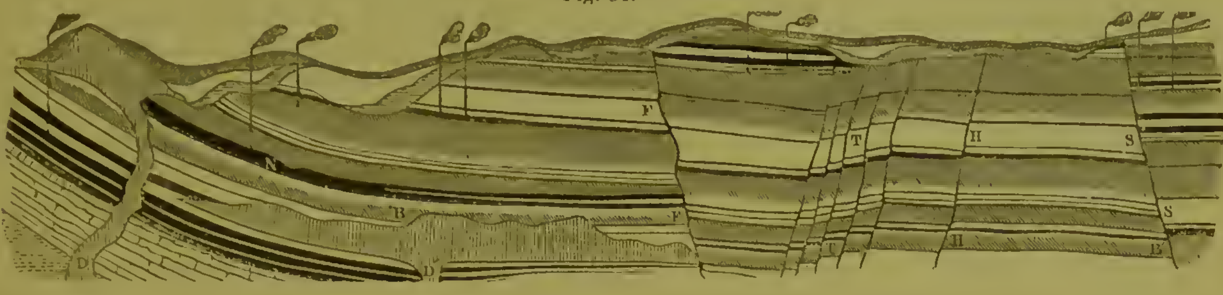


Fig. 54.



into compartments, which are designated *fields*. Besides this term, another is applied significant of the displacement of the bands of coal from their original position—namely, *shifts*. Where these occur, the seam is thrown out of its level, and, according as it is removed to a higher or lower one, the fault is called an *up-throw* or a *down-throw*. The displacement occurring at many of these shifts is considerable, and gives no small trouble to the miners. The largest known is that which runs through the Northumberland and Durham coal-field, and is termed the Ninety-fathom dyke, from the fact that the seams of coal are ninety fathoms lower at one side of the slip than at the other. Various matters fill these intersecting veins; hard and soft sandstone is contained in the one in question, which in some parts, especially at the Montague Colliery, attains a width of twenty-two yards. Two other dykes spring from this at the Southern side; one of which takes a South-eastern direction, and is about twenty yards in breadth; the other a South-western one, and attains a breadth of seventy yards. Both branches are filled with the same material as the primary one, but do not appear to have caused so great a disturbance at their point of intersection. These are represented in the foregoing drawing at F F, S S; but the others, although they partake of the nature of a dyke, are not recognised as such. For instance, those shown at D D′ are of a different character, and are called *whin*-dykes, containing products of igneous origin, such as basalt, toadstone, *et cetera;* these do not always cause a removal of the strata from the ordinary level. Evidence of their eruption in a state of fusion exists in the fact, that the coal in their vicinity is more or less charred and converted into a true coke; besides, many substances of a fusible nature are acted upon, and indicate the powerful temperature which has pervaded the place, and which is often productive of great loss by consuming or changing the coal into anthracite, as shown at D′ in the figure, where the basalt and other products accumulate. The *hitch* is another of those dykes, and is so called when its thickness is less than that of the seams of coal which it intersects: this is represented at H H in the drawing. Smaller veins of foreign matters lying in any direction contrary to that of the strata are designated *faults* or *troubles*, from the annoyance the miners experience by the interruption of their work. Several of these are seen at T T; and although in working they cause much trouble, yet sometimes they contribute to render a field more valuable, since, by the depression which they occasion, seams of coal are brought in which might otherwise be lost. An example of this is given in the drawing referred to, where, by the down-throw of the strata between F F and T T, two seams of coal are brought in which would not otherwise be contained in it. Other interruptions or irregularities in the coal seams are designated *bands* and *nips;* the former, shown at B, are thin deposits or beds of grit or shale occurring in the middle of a seam of coal, and which, from being very thin, gradually acquire greater thickness, till ultimately they reduce the seam so much as to render it valueless; the second, shown at N, is a sudden local thinning of the seam, from an excrescence of the roof or floor.

The distribution of coal is very extensive; it is found in almost every country, although to a very unequal extent. The United States may be considered as the most highly favored in this respect, if the area of their coal deposits be taken into account, irrespective of the extent to which they are worked. It happens, however, that, from the abundance of wood, the home consumption of the article is limited, while the conveyance is costly, so that the benefits which result from valuable coal seams in other nations, remain to be developed in America. According to the statistical calculations of Mitchell, the annexed table represents the amount and varieties of the mineral coal treasures in the United States:—

TABLE SHOWING THE AREA OF COAL IN THE UNITED STATES OF AMERICA.

	Area of the State. Square Miles.	Coal Areas. Square Miles.	Proportion of Coal.	Species.
1. Alabama,	50,875	3,400	1-14th	Bituminous coal.
2. Georgia,	58,200	150	1-386th	"
3. Tennesse,	44,720	4,300	1-10th	"
4. Kentucky,	39,015	13,500	1-3rd	"
5. Virginia,	64,000	21,195	1-3rd	"
6. Maryland,	10,829	550	1-20th	"
7. Ohio,	38,850	11,900	1-3rd	"
8. Indiana,	34,800	7,700	1-5th	"
9. Illinois,	59,130	44,000	3-4ths	"
10. Pennsylvania,	43,960	15,437	1-3rd	Bituminous and Anthracite.
11. Michigan,	60,520	5,000	1-12th	"
12. Missouri,	60,384	6,000	1-10th	"
	565,283	133,132	nearly 1-4th the area of the twelve States.	

It is certain that this vast tract of carboniferous deposit is not in its whole extent calculated to yield workable coal; still, making every allowance for those parts which, from their thinness or depth, cannot be profitably worked, it is evident that the area is sufficient to insure, for an almost indefinite period, a superabundant supply. Although within the last thirty years the coal trade of the United States has increased from an annual produce of three hundred and sixty-five tons to five millions of tons, yet it must be evident at a glance that this enormous source of wealth is permitted to lie comparatively dormant at the present day. In British America the coal measures are not so extensive as in the States; it is doubtful, indeed, whether any workable seams exist in Canada, but fields of considerable area are known in New Brunswick and Nova Scotia, making about two-ninths of the whole area; and Newfoundland is said to be rich in this mineral.

TABLE OF THE PRINCIPAL COAL FIELDS IN THE BRITISH ISLES.

	Estimated workable area in acres.	Number of workable seams.	Estimated total thickness of workable coal in feet.	Thickest bed in feet.	Thickness of coal-bearing measures.
1. NORTHUMBERLAND AND DURHAM DISTRICT:—					
Newcastle coal field,	500,000	18	80	7	..
2. CUMBERLAND AND WESTMORELAND, AND WEST RIDING OF YORKSHIRE:—					
Whitehaven and Akerton,	80,000	7	..	8	2,000
Appleby—three basins,	17,000	..	..	..	..
Sebergham—Cumberland,	?	1	3	3	..
Kirkby-Lonsdale,	2,500	4	17	9	..
3. LANCASHIRE, FLINTSHIRE, AND NORTH STAFFORDSHIRE:—					
Lancashire coal field,	380.000	75	150	10	6,000
Flintshire,	120,000	5	39	9	2,000
Pottery—North Staffordshire,	40,000	24	38	10	..
Cheadle, do.,	10,000	..	..	..	..
4. YORKSHIRE, NOTTINGHAMSHIRE, AND DERBYSHIRE:—					
Great Yorkshire coal field,	650,000	12	32	10	..
Darley Moor, Derbyshire,	1,500	..	..	..	..
Shirley Moor, do.,					
5. SHROPSHIRE AND WORCESTERSHIRE:—					
Coalbrook Dale, Shropshire,	21,000	17	40	..	..
Shrewsbury, do.,	16,000	3	..	..	..
Brown Clee-hill, do.,	1,300	3	..	..	..
Tillerstone Clee-hill, do.,	5,000	..	..	..	.
Leekey-hill, Worcestershire,	650	?	..	..	..
Bewdley, do.,	45,000	?	..	..	..
6. SOUTH STAFFORDSHIRE:—					
Dudley and Wolverhampton,	65,000	11	67	40	1,000
7. WARWICKSHIRE AMD LEICESTERSHIRE:—					
Nuneaton,	40,000	9	30	15	..
Ashby-de-la-Zouch,	40,000	5	33	21	..
8. SOMERSETSHIRE AND GLOUCESTERSHIRE:—					
Bristol,	130,000	50	90	..	..
Forest of Dean,	36,000	17	37	..	..
Newent, Gloucestershire,	1,500	4	15	7	..
9. SOUTH WELSH COAL FIELD,	600,000	30	100	9	12,000
10. SCOTTISH COAL FIELDS:—					
Clyde Valley,	1,000.000	84	200?	13	6,000
Lanarkshire,					
South of Scotland—several areas,					
Mid-Lothian,	?	24	94	..	4.400
East-Lothian,	?	60	180	13	6,000
Kilmarnock,	?	3	40	30	..
Ayrshire,					
Fifeshire,	?	?	?	21	..
Dumfries coal region,	45,000	10	55	6	..
11. IRISH COAL FIELDS:—					
Ulster,	500.000	9	40?	6	..
Connaught,	200.000	..	..	..	..
Leinster—Kilkenny,	150,000	8	23	..	..
Munster—several,	1.000,000	..	..	..	..

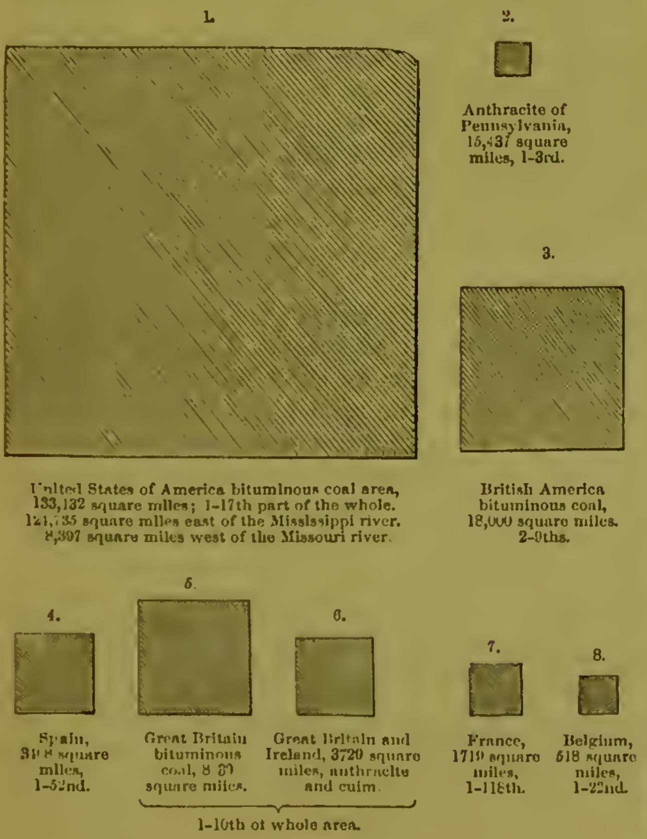
In the area of her coal deposits, Britain ranks next to the United States, and greatly exceeds the latter in the extent and value of her workable mines. The total extent of coal in England is estimated at about six thousand and thirty-nine square miles, or one-eighth of the whole area; in Scotland, one thousand seven hundred and twenty square miles, or one-eighteenth of the whole; and in Wales, one thousand one hundred and sixty square miles, or about one-sixth of its entire extent. The principal deposit is that known as the great central coal-field, lying in South Yorkshire, Nottingham, and Derby; it is no less than sixty-five miles in length, and averages in some parts a breadth of twenty-five, making on the whole an area of about six hundred and fifty thousand acres. Next to this may be classed the Lancashire and Cheshire field, including the Wigan district; this deposit is about fifty miles in length, with an average breadth of ten miles, and is, therefore, no less than four hundred thousand acres in area. Another field, which seems an extension of the latter, runs from its south-eastern extremity through Cheshire into Staffordshire, in which are the Cheadle, Macclesfield, and Pottery coal-fields. The third great deposit is that of Durham and Northumberland, which stands probably first in the list as to the quantity of fuel that is obtained from it. This vast deposit—called also the Newcastle coal-field—is estimated at thirty-six thousand acres situated in Durham, and about one hundred and fifty thousand acres in Northumberland. Of this extent about sixty-seven thousand acres are already worked. Estimating the content of this field at a thickness of twelve feet, each acre of four thousand eight hundred and forty square yards is supposed to yield a ton of coal per cubic yard, thus making the total weight of coals in this field about ten million tons, including the quantity destroyed and rendered unserviceable.

Besides the above, there are several other mines of secondary importance, from which a considerable quantity of coal is annually extracted. These, with their area, thickness, the number of workable seams, *et cetera*, are exhibited in the table in previous page, which is extended to embrace Great Britain and Ireland.

On the Continent the chief coal-producing countries are Spain, France, Belgium, and Prussia, although several others possess many valuable coal basins which hitherto have been little worked. The following diagram—Fig. 55—taken from Taylor's work, gives a moderately comprehensive view of the comparative area of coal in the various countries that have been mentioned. It includes not only the workable seams, but the entire carboniferous area :—

DIAGRAM OF THE SUPERFICIAL COAL AREAS OF VARIOUS COUNTRIES.

Fig. 55.



United States of America bituminous coal area, 133,132 square miles; 1-17th part of the whole. 124,735 square miles east of the Mississippi river. 8,397 square miles west of the Missouri river.

Anthracite of Pennsylvania, 15,437 square miles, 1-3rd.

British America bituminous coal, 18,000 square miles. 2-9ths.

Spain, 3408 square miles, 1-52nd.

Great Britain bituminous coal, 8139 square miles.

Great Britain and Ireland, 3720 square miles, anthracite and culm.

1-10th of whole area.

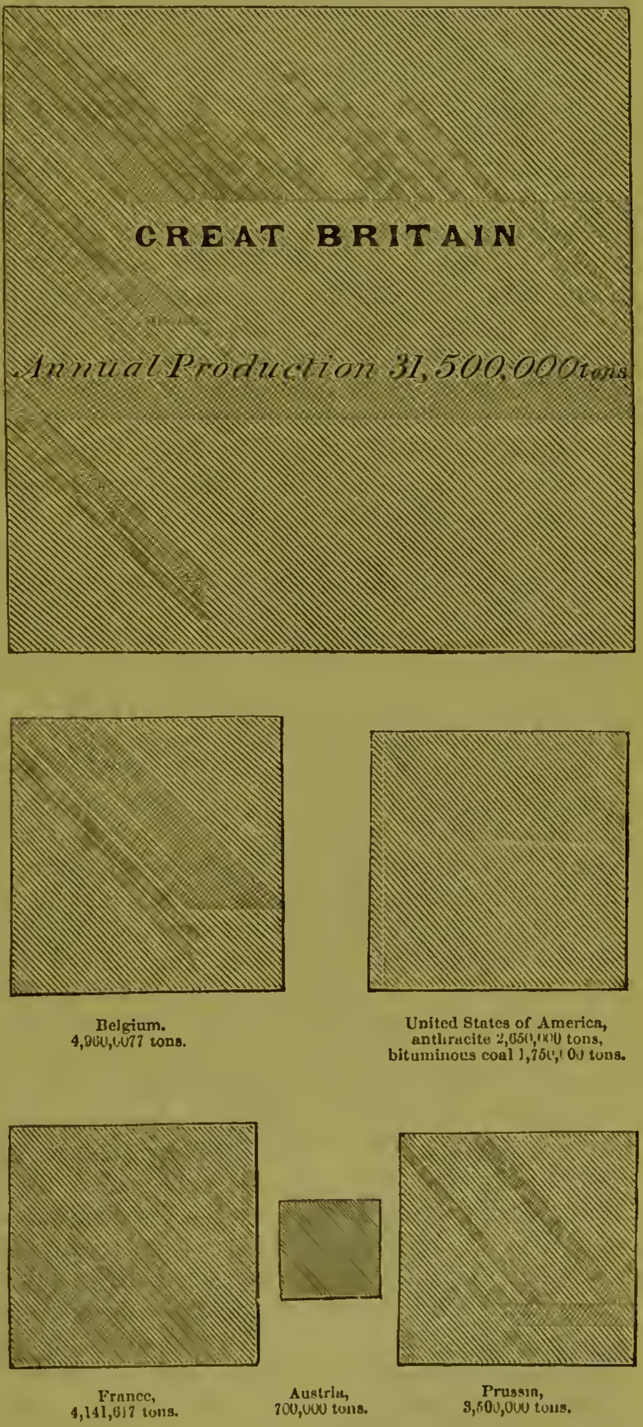
France, 1719 square miles, 1-118th.

Belgium, 518 square miles, 1-22nd.

It is evident, however, that this diagram, with its numbers, does not exhibit the relative value of the coal-fields in the different countries. This must depend on many circumstances, apart from the mere consideration of superficial extent; but their productiveness at the present day is shown in the next diagram—Fig. 56.

DIAGRAM OF THE RELATIVE AMOUNTS OF PRODUCTION OF MINERAL COMBUSTIBLES IN THE SIX PRINCIPAL COAL-PRODUCING COUNTRIES OF THE WORLD, IN THE YEAR 1845.

Fig. 56.



Belgium. 4,960,077 tons.

United States of America, anthracite 2,650,000 tons, bituminous coal 1,750,000 tons.

France, 4,141,617 tons.

Austria, 700,000 tons.

Prussia, 3,500,000 tons.

A summary of the whole, exhibiting at one view the extent of coal area, the quantity raised in 1845, with its relative proportion to the area, and, finally, the official estimated value of the places of production, is added in the annexed table :—

Countries	Square miles of coal formation.	Tons of fuel raised in 1845.	Relative parts of 1000.	Official estimated value of the places of production.
Great Britain, ...	11,859	31,500,000	642	9,150,000
Belgium,..........	518	4,960,077	101	1,660,000
United States,....	133,132	4,400,000	89	1,373,000
France,........ ..	1,719	4,141,617	84	1,603,106
Prussian States,...	not	3,500,000	70	856,370
Austrian States,...	defined.	659,340	14	165,290
Total,........		49,161,034	1000	15,108,729

It may be added, as the result of recent researches, that Asia and even Africa have been found to be very well stocked with fossil fuel; and, indeed, there can be little doubt that the East Indies and China will yet become coal-producing countries. The same may be said of Australia, and other British colonies.

DIFFERENT KINDS OF COAL.—From the acknowledged transformation which the substance of the coal has undergone, and from its progressive nature, it is natural to expect that the material so produced should have very different properties, according to its more or less advanced state of decomposition. Such is really the case, and various species of coal exist differing by slight and regular gradations from the most recent lignite or brown coal, in which the outline of the wood may be easily traced, up to the most perfect anthracite, in which every vestige of the original is lost, and nothing remains but a conglomerated charcoal. Many of them, indeed, have so close a resemblance to one another, and pass so imperceptibly from one stage to the other, that it is almost impossible to mark the distinction between them. Several species, however, may be classified on broader data, grounded partly upon age, partly on their physical appearance, and partly on their composition. It is by these criteria that the classification of the fossil into brown and black coal, or into the bituminous and non-bituminous varieties, is effected. Several members are contained in each of these groups, but many kinds blend with each other in such a manner that it is difficult to draw a line of demarcation between them. Classifying the chief varieties according to their supposed age, the whole of the coal measures may be included under three heads; namely, the younger coal of the *tertiary* deposits, the older bituminous kind of the secondary formations, and the anthracites of the older transition series of rocks.

Lignite.—The coal of the tertiary formation, which includes several varieties, has been designated *brown coal* or *lignite*, from its characteristic appearance. This species, termed also bituminous wood, is the most interesting, as clearly exhibiting the ligneous structure of the matter from which it derives its name, in such perfection as to furnish sufficient data for instituting a diagnosis of the plants of very remote eras. It has a brown color; but this varies with the depth of the bed. The Bovey coal of Devonshire is a member of this class; it presents a distinct woody structure, and very rarely a conchoidal fracture; it is devoid of lustre, is brittle, and burns readily, leaving a white ash. Some others, however, such as the more compact kinds, exhibit a more or less conchoidal fracture and slightly resinous lustre. In the latter case, the color is brownish-black; it has been called earthy-brown coal, to distinguish it from another kind of the same species, designated *pitch coal*, the structure of which is more dense, as shown by its distinct conchoidal appearance when broken. Between these extremes may be found the *brown earthy coal*, so named from its argillaceous fracture, crumbling into loose friable particles; and *moor coal*, in which the structure of the plants is obliterated, and which exhibits in its fracture more or less lustre.

The species of coal embracing these varieties is encountered in several of the formations on the Continent; at Bovey Tracey in Devonshire, near Lancaster, and at Lough Neagh in Ireland, where it constitutes three beds, averaging in some parts a thickness of sixty feet. It is very inferior as a fuel to the other varieties of coal which will be presently described. As dug from the mine it is more or less impregnated with moisture, which it persistently retains, and which, even if entirely expelled, is reabsorbed with great avidity. Thus REINSCH determined in a sample of wood coal from the Upper Pfalz, in Bavaria, forty-three per cent. of moisture, and in an earthy-brown coal, thirty. VARRENTRAPP found no less than forty-eight per cent. of moisture in fresh lignite from Helmstadt, and further ascertained that, after thorough desiccation and re-exposure to air, about eight per cent. of water was again absorbed. By stacking this coal for some time, much of the water evaporates, so that the moisture averages about thirty per cent.; but if the exposure be made in summer, the quantity is lessened to twenty per cent., the bulk of the coal undergoing a corresponding reduction.

Distinct from the foregoing in physical appearance, though to some degree analogous in chemical composition, are those non-compact bodies, termed bituminous coal, in which the structure of the plants is entirely effaced, and the color and appearance are indicative of a pretty advanced stage of decomposition. Of this kind there are several varieties, distinguished by characteristic properties. When treated with ether they all yield more or less bitumen, and hence the general designation, *bituminous*, to distinguish them from the anthracites proper, which afford none of that substance. The following most marked varieties of this description are *caking coal*, *splint coal*, *cherry coal*, and *cannel* or *parrot coal*.

Caking coal is a moderately compact fuel; its fracture is uneven, and its lustre varies from a resinous to a velvety or greyish-black appearance. When heated, it breaks into small pieces, if the amount of bitumen be not more than the average, but afterwards the fragments agglomerate, and form a hard compact body; when the per centage of bitumen is high, it fuses at once into a pasty mass, and during the application of the heat bubbles of gaseous matter escape, leaving ultimately a carbonaceous substance, in which all traces of the original are effaced. Ignited in air, it burns with a yellowish flame, which is intermittent, unless the fuel be kept repeatedly stirred, so as to prevent its caking. The latter tendency renders this coal unsuitable for many operations where great heat is required, as the draught is impeded by its caking properties. It is, however, a valuable fuel, especially as it is very often possessed of qualities which render it applicable for the manufacture of gas and coke, the latter being most eligible as a heating agent where the coal itself cannot be employed.

Caking coal is very general, being met with in almost all the coal-fields of Great Britain, but more especially in the Newcastle and Wigan districts.

Splint or Hard Coal.—This variety occurs most abundantly in the Glasgow coal deposits, where, for general application, it is highly prized. Its color is black or brownish-black, and its lustre resinous and glistening. When broken, the principal fracture appears imperfect and slaty, but the transverse one shows it to be fine-grained, uneven, and splintery; hence, as well as from its hardness, the term splint. It kindles with greater difficulty than the preceding variety, but when once ignition has taken place, it produces a fine clear fire, and throws out much heat.

Cherry or Soft Coal.—The similarity in physical appearance between this and the caking coal is very great, though for the most part the lustre of cherry coal is much more splendent, and hence the name given it by the miners. It differs from caking coal in not undergoing fusion when heated. Owing to its great brittleness, it is not economical in the working. It readily ignites, and makes a lively fire, yielding a clear yellow flame, but is consumed rapidly. This species is likewise met with in the upper strata of the Glasgow beds, as also in Staffordshire, in the Lancashire district, *et cetera.*

Cannel, Candle, or Parrot Coal.—This variety has a very compact and even texture; a shining resinous lustre, and a color varying between a jet and a greyish or brownish black. The lustre of cannel coal is sometimes not so very distinct as that of *pitch coal*, which is a species of the caking kind; its compact texture and gravity are sufficiently characteristic to distinguish it from the other sorts. The fracture of cannel is flat, conchoidal in every direction, and sometimes slaty. It takes a good polish, and on this account is manufactured into numerous articles, such as inkstands, snuff-boxes, beads, *et cetera.*

Cannel is found in several coal basins, but most abundantly in the Wigan district, at Lesmahagow, near Glasgow, and at Coventry. It is so named from its property of burning and yielding a bright flame like a candle. The other name, *parrot coal*, which is of Scottish origin, is derived from its decrepitation when thrown on the fire, owing to pieces of the coal flying off when heated.

Many other local appellations are given to the coal even from the same field, if it includes many seams, but these are of little interest to the consumer.

Anthracite.—In speaking of the origin of coal, allusion has been made to this variety as being the oldest, and, consequently, the furthest removed from its vegetal source in composition and physical characters. This fossil, which is sometimes known as *glance* or *stone* coal, is a hard compact substance possessing much lustre, often iridescent; the more perfect variety is entirely free from bituminous matter, and hence it constitutes a class of the coal formation in itself. These characters are not observed in all the anthracites, which generally retain more or less bituminous coal interstratified or otherwise mixed with portions reduced to the state of true anthracite. The mixed varieties, or semi-anthracites, admit of being employed as a substitute for caking coals in many cases where a true anthracite would not answer the purpose.

This is the densest of all the coals known, excepting such as are very earthy or otherwise mineralized. It contains, when a true anthracite, only carbon, water, and inorganic salts, but generally more or less hydrogen and oxygen, besides the proportion of the latter elements in the form of water. Anthracite is ignited with great difficulty, and being dense, and having a tendency to break up into fragments when heated, in consequence of the expulsion of the water contained in it, it is not calculated to produce a strong fire in the ordinary grate or furnace, although, when once thoroughly ignited, its calorific power is very great. By a suitable modification of the grate or furnace, and proper management, it may in numerous instances—not the least of which is its application to smelting—be employed with advantage.

Anthracite is found most extensively in America, where it constitutes immense deposits. In England, it is chiefly worked in the South Wales coal-field, although it may be met with in large quantities in other basins. The total area of this description of fuel in Great Britain and Ireland is about three thousand seven hundred and twenty acres.

CHEMICAL COMPOSITION OF COAL.—The localities and general characteristics of the principal varieties of coal having been noticed, the Editor will proceed to a more minute examination of its composition. It has been already laid down as a general principle, that the value of a fuel is proportional to the amount of carbon which it contains. Like other rules, however, this admits of exceptions, and, for some purposes, the coal is valued according to its per centage of hydrogen. This is especially the case with coal intended for gas manufacture, and also when employed as a fuel in such arts as require the heat to exert its power at some distance from the fire. Moreover, other ingredients may be contained in the coal in proportions very insignificant when compared with the carbon and other inflammable portion, but still so injurious in their effects as to render the fuel unadapted for many purposes to which it might otherwise be applied with good results. Among these are found sulphur, arsenical and other kinds of pyrites; and similar prejudicial effects are produced by the presence of considerable portions of sulphates, or, in fact, of any mineral matters which undergo no change during the combustion. The pyritous ingredients are, however, the most deleterious, as during combustion they evolve sulphurous acid, and if arsenic be contained in the coal—which is fortunately a rare occurrence—arsenious acid will be eliminated. Now, both the sulphurous and arsenious acids are highly obnoxious and dangerous, and ought to be avoided as much as possible. From all these considerations, it is evident that, to determine the quality of any species of coal, with a view to ascertain its fitness for a given purpose, nothing short of a knowledge of its ultimate composition can be relied on; and this can only be arrived at by careful analyses. Before proceeding further, therefore, the differences in chemical composition of the principal varieties will be examined.

Lignites.—It has been stated that this species of coal belongs to the tertiary or latest formations, and retains much of the ligneous structure from which it derives its name. The general results of its distillation are a coke or charcoal containing mineral matters—aqueous products, more or less charged with pyroligneous acid and ammonia, tar, carbides of hydrogen, carbonic oxide, and carbonic acid. The relative proportions of these vary in different specimens; but, on the whole, they exhibit a great similarity of composition in this substance, as compared with peat and wood—more especially the former. By further treatment the analogy is more fully established: thus, when lignite is treated with caustic potassa, it dissolves, yielding a dark-brown liquor, which affords a substance resembling in its reactions ulmin, the principal ingredient of peat. Again, the coke which remains after the distillation of lignite retains the outline of the sample operated upon, just as in the case of peat or wood, a circumstance which happens with no other kind of coal. It is to be observed, however, that these characteristics apply only to strongly-marked lignite or brown coal. The transition from this to true coal is gradual, both as regards the physical and chemical properties. The composition of lignite varies according to the age and position of the deposit, but this difference is chiefly confined to the mineral and aqueous constituents.

The following table, from RICHARDSON and RONALDS, exhibits the inorganic constituents of various lignites and brown coal:—

	Variety of Brown Coal or Lignite.		Ash.	Observer.
Bohemian,	Lignite from Aussig,		5.35	Balling.
	" "		5·51	
	" Hegendorf,		6·93	
	" Neuendorf,		5·13	
	" Coulang,		1·50	
	Earthy, from Grünlas,		6·66	
Bavarian Ob-Pfalz,	" Verau,		10·00	Reinsch.
	Lignite from "		3·40	
	" Grecce,		9·02	Regnault.
	" Usnach,		2·19	
	" Cologne,		5·49	
	Earthy brown coal from Dax,		4·99	
	" " Bouches du Rhône,		13·43	
	" " Nieder-Alpen,		3·01	
Cassel,	" Stangen—coal,	Meissner,	15·47	Kühnert.
	" pitch—coal,		2·43	
	" " Herschberg,	Ringkuhl,	0·81	
	Pitch coal,		2·76	
	Middle sort,		3·30	
	Lowest sort,		4·92	
	Pitch coal from Habichtswald,		1·33	
	" "		3·33	
	Stillberger coal, Söhrwald,		6·95	
	Lignite from Hirschberg,		1·29	
From Duren, on the left bank of the Rhine,	" Iceland,		8·80	Karsten.
	" " another specimen,		27·50	
	" Utweiler,		0·90	
	" Grube Urwelt,		4·60	
	" " "		27·05	
	" Friesdorf,		1·69	
	" " "		14·90	
Near Boom, on the right bank of the Rhine,	" Putzchen,		4·40	
	" " "		17·40	
	" Stösschen,		14·40	
	" " "		28·20	
	" Orsberg,		43·20	
	" " "		58·00	
	Coal from Schöningen,	Brunswick,	7·80	Varrentrapp.
	" Helmstädt,		8·40	
	Slate coal from Azberg,		4·50	Reinsch.
	" Aga Reuss,		6·00	
	Earthy lignite from Wigan,		4·95	J. A. Phillips.
	" Conception Bay,		7·49	Admiralty Coal Investigation.
	Lignite from Sandy Bay, Patagonia,		13·29	
	" Talcahuano Bay,		6·92	
	" Altern, Germany,		1·16	Kremers.
	" Lough Neagh, Ireland,		6·84	
	" Isle of Madeira,		20·05	Johnston.

Thus it will be observed, that the inorganic matters contained in brown coal or lignite vary from less than one to nearly sixty per cent. For example, the amount of ash in a species of pitch coal from Herschberg is only 0·81 per cent., while, in a variety from the bank of the Rhine, it is 58 per cent. But those which contain the larger amount can scarcely be classed with fuels, as they cannot be economically used in that capacity, except, perhaps, for the combustion of shaly matters, as in the manufacture of alum, *et cætera*. A much closer coincidence is found between the elementary composition of the organic matter in different specimens than appears in the mineral portion, as is shown by the annexed tabulated results of the analysis of several varieties, also transcribed from the able work of RICHARDSON and RONALDS:—

ELEMENTARY ANALYSES OF BROWN COAL.

Brown Coal or Lignite.	Centesimally. Carbon.	Hydrogen.	Oxygen and Nitrogen.	Observer.
Earthy, from Dax,	69·52	5·59	19·90	Regnault.
" Bonches du Rhône,	63·01	4·58	18·98	
" Neider-Alpen,	69·05	5·20	22·74	
Earthy—consisting of stems—from Meissner,	70·12	3·19	7·59	Kühnert.
" pitch coal,	56·60	4·75	27·15	
" " from Ringkuhl, Hirschberg,	60·83	4·36	24·64	
" " " Habichtswald,	57·26	4·52	26·10	
" lustrous coal, Ringkuhl,	66·11	4·82	18·51	
" allied to pitch coal, Habichtswald,	54·18	4·20	26·98	
" lowest vein at Ringkuhl,	52·98	4·09	21·91	
" middle,	54·96	4·01	22·31	
" Stillberger,	50·78	4·62	21·38	
" Helmstadt, Prince of Wales mine,	68·57	4·84	19·87	Varrentrapp.
" " another mine,	67·88	6·85	17·46	
" Schönengen Treue mine,	63·71	5·07	22·79	
" " another pit,	64·80	4·54	23·12	
Lignites from Ringkuhl,	51·70	5·25	30·37	Kühnert
" Greece,	60·36	5·00	25·62	Regnault.
" Cologne,	63·42	4·98	27·11	
" Usnach,	55·27	5·70	36·84	
" Laubach,	57·28	6·03	36·10	Liebig.
Earthy brown coal from Wigan,	80·21	6·30	8·54	J. A. Phillips.
" " Conception Bay,	70·33	5·84	16·34	Admiralty Coal Investigation.
Lignite from Sandy Bay, Patagonia,	62·19	5·08	19·44	
" Talcahmano Bay,	70·71	6·44	16·93	
" Lough Neagh, Ireland,	58·56	5·95	26·85	Kane.
" " " another sample,	51·36	7·35	25·08	

The average content of nitrogen ranges from 0·5 to 1·5 per cent. Taking the mean of the numbers representing the components of the true lignites, the results would indicate the annexed composition:—

	Centesimally.
Carbon,	63
Hydrogen,	5
Oxygen and nitrogen,	32
	100

But if the whole of the oxygen be assumed to be united with the hydrogen so as to form water, the actual constitution of the substance would be represented by sixty-three parts of carbon, one of hydrogen, and thirty-six of water. Some varieties of this species of coal are used in the manufacture of various articles of ornament, especially in France, where the business is carried on with considerable success.

Bituminous Coals.—Bituminous coal bears a general resemblance to the last, inasmuch as both contain the same substances, varying in relative quantity. Analysis, however, cannot always determine between them, and the physical marks noted in the preceding pages must be observed narrowly before deciding. For the most part, the density of bituminous coal is greater than that of the lignite or brown coal, unless the latter be very earthy and compact. REGNAULT gives the density of the varieties of lignite which he examined, when in the dry state, as between the extremes of 1·100 and 1·85. Earthy coal he found to have a specific gravity of 1·254 to 1·276; but other varieties afforded KUHNERT a density of 1·310 to 1·436. Many of these numbers are much higher than that of the densest bituminous coal; but this must be attributed to the superabundant presence of mineral matters. At the same time, the gravity of a true homogeneous coal is not always to be inferred from the amount of ash which it yields, although some investigators have endeavored to establish a constant relation between the density of the coal and its inorganic constituents. It is evident, indeed, that a substance may be very dense in its nature, and yet, from its state of aggregation, may give but a medium indication when its gravity is determined in bulk. This has been observed in the case of wood and charcoal, and equally applies to the substance under examination.

The subjoined table, derived from the same authorities as the preceding ones, expresses the per centage of ash or mineral matters yielded by the several samples of coal mentioned, together with the specific gravity:—

Description of coal.	Locality.		Specific gravity.	Per centage of ash.	Observers.
Splint,	Wylan Banks, Newcastle,		1·302	13·912	Richardson.
	Glasgow coalfield,		1·307	1·128	
Cannel,	Wigan, in Lancashire,		1·319	2·545	
	Parrot coal, Edinburgh,		1·318	14·566	
Cherry,	Jarrow, Newcastle,		1·266	1·676	
	Chief mass of coal from Glasgow,		1·286	1·421	
Caking,	Garesfield, Newcastle,		1·280	1·393	
	South Hellon, Durham,		1·274	1·519	
Coal Measures,	Alais, Rochebelle,	fat and hard coal	1·322	1·410	Regnault.
	P've de Gier—P. Henry,		1·315	2·960	
	Flenu from Mons,	fat coal producing a long flame	1·276	2·10	
	" "		1·292	3·68	
	Cimetière Rive de Gier,		1·288	3·57	
	" " "		1·294	2·99	
	Couzon,		1·298	2·72	
	"		1·311	5·32	
	Lavaysse,		1·284	5·13	
	Epinac,		1·353	2·53	
	Commentry,		1·319	0·24	

Description of coal.	Locality.	Specific gravity.	Per centage of ash.	Observers.
Coal Measures,	Blanzy—dry coal, long flame,	1·362	2·28	Regnault.
	Rive de Gier, Grand Croix, { fat and hard coal }	1·298	1·78	
	“ “ “ “	1·302	1·44	
Secondary Formation,	Anthracite, Lamure, Dep. de l'Isère,	1·362	4·57	
	“ Macot,	1·919	26·47	
	Common coal, Obernkirchen Lippe-Sch	1·279	1·00	
	Ceral, Dep. Aveyron,	1·294	11·86	
	Noroy Vogesen,	1·410	19·20	
	St. Girons,	1·316	4·08	
	Belestet,	1·305	0·89	
	Cznernitz, Upper Silesia,	1·362	5·80	Karsten.
	Gnade Gattes, Lower Silesia,	1·285	4·65	
	Glück hülf,	1·276	0·80	
	Sulzbach, Duttweiler Saarbrücken,	1·258	0·15	
	Wettin, Saalkreis,	1·466	24·40	
	Sälzer and Neuack, Westphalia.	1·288	0·70	
	Pottschappel, Saxony,	1·454	27·7	
	Königen Louise, Upper Silesia,	1·280	0·2	
	Königsgrubbs,	1·285	0·6	
	Merchweiler Saarbrücken.	1·282	0·9	
	Freschauf, Lower Silesia,	1·518	23·4	
	Brazils,	1·183	28·4	
	Coarse coal, mixed with pitch coal,	1·48	20·9	Lampadius.
	Slate coal,	1·24	22·7	
	“ “ with fibre coal,	1·20	26·3	
	Anthracite,	1·37	22·5	
	Slate coal, with a little fibre coal,	1·25	20·2	
	Hard slate coal, with layers of pitch coal,	1·42	24·0	
	Slate coal, with predominating layers of anthracite and fibre coal,	1·35	23·4	

From this table it may be seen that the specific gravity of coal ranges from 1·2 to 1·5, rarely exceeding the latter; and further, by rejecting those samples which yield very large per centages of ash, the mean gravity will be about 1·30. It will also be observed, that the relation existing between the mineral constituents of the coal and the density is quite irregular, and, consequently, offers no trustworthy grounds for inferring the per centage of ash which a coal may contain merely by determining the density, or inversely. It is true, however, that in numerous instances, samples with a larger proportion of ash will be found to have a higher density than those which contain less inorganic matter. This is more especially the case with different samples of coal from the same mine, which led JOHNSON to infer that the specific gravity and mineral constituents of the coal from the same bed have a constant relation to one another. The basis on which he erected this theory, is found in the following results of the analyses of four samples of coal from Beaver Creek, Lucerne County:—

	Specific gravity.	Per centage of ash.
No. 1,	1·560	1·28
“ 2,	1·594	4·00
“ 3,	1·613	5·01
“ 4,	1·630	5·063

The same increase was observed with four other samples from the coal field of Maryland, bordering on Pennsylvania, thus:—

Mean specific gravity of two specimens.	Mean per centage of earthy matters in two specimens.
1·320	7·52
1·350	9·58
1·365	10·35
1·385	11·75
1·485	14·41

Admitting that a high density is to some extent an indication of the presence of mineral matters in greater abundance, yet it is impossible, even approximately, to estimate the per centage of these by this test, since no fixed and constant relation can be established between the two. Besides, it is well known that a great difference in the amount of mineral matters is sometimes detected in coal from the same working.

The nature of the inorganic matters in coal affects, in a great degree, not only the gravity of the substance, but its quality as a fuel, although the components found are generally the same in all. From the tables already given, it will be seen that the total quantity of ashes fluctuates between one and twenty-five per cent., the average being about ten per cent. or under. The following table of the analyses of the ashes of coal by PHILLIPS, shows the nature and extent of the components, which, strange to say, contain no alkalies:—

NAME.		Silica.	Alumina and oxide of iron.	Lime.	Magnesia.	Sulphuric acid	Phosphoric acid.	Total per centage.	Per centage of ash in coals.	Per centage of coke in coals
Welsh.	Pontypool,	40·00	44·78	12·00	trace.	2·22	0·75	99·75	5·52	64·8
	Bedwas,	26·87	56·95	5·10	1·19	7·23	0·74	98·08	6·94	71·7
	Porthmawr,	34·21	52·00	6·199	0·659	4·12	6·633	97·821	2·91	63·1
	Ebbw Vale,	53·00	35·01	3·94	2·20	4·89	0·88	99·92	14·72	77·5
	Coleshill,	59·27	29·09	6·02	1·35	3·84	0·40	99·97	10·70	—
Scotch.	Fordell, Splint,	37·60	52·00	3·73	1·10	4·14	0·88	99·45	1·50	52·03
	Wallsend, Elgin,	61·66	21·12	2·62	1·73	8·38	1·18	99·99	4·0	58·45

The annexed table exhibits the composition of American coals according to Professor JOHNSTON:—

Character and Composition of the Ashes.	Sugarloaf Company's Anthracite, 1st specimen, specific gravity 1·591.	Sugarloaf Anthracite, 2d specimen, specific gravity 1·574	Sugarloaf Anthracite, 3d specimen, specific gravity 1·55.	Buck Mountain Anthracite, specific gravity 1·559.	Summit Coal Company's Anthracite, head of Beaver Creek, 1st specimen, specific gravity 1·613.	Summit Company's Anthracite, 2d specimen, specific gravity 1·514	Stephenson's Bluff Anthracite, Beaver Creek, specific gravity 1·612.	Salem-vein Anthracite, Pottsville, specific gravity 1·530.	Quin's Run Bituminous Coal, specific gravity 1·372.
Per centage of ashes in the coals,....	4·83	8·73	2·242	3·079	5·01	4·00	3·71	6·75	6·80
Color of ashes,....................	Light-buff.	Reddish-white.	White.	Reddish-buff.	Fawn.	Reddish-grey.	Fawn.	Brick-red.	Grey.
Silica,..........................	53·603	45·105	43·68	45·60	54·50	50·25	50·05	50·00	76·00
Alumina,.........................	36·687	37·000	39·34	42·75	34·45	38·90	39·04	38·90	21·00
Sesquioxide of iron, ...	5·590	13·000	8·22	9·43	7·50	8·75	8·75	8·00	2·60
Lime,............................	2·857	1·380	5·76	1·41	2·25	0·85	1·56	2·10	..
Magnesia,........................	1·076	2·430	3·00	0·33	1·30	1·25	1·30	0·90	..
Oxide of manganese, ...	0·186	—	..	..	..	..	..	..	..
Loss per cent.,....................	0·001	1·085	..	0·48	..	..	..	0·10	0·40
	100·000	100·000	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The same elements are contained in the ashes of brown coal, though in different proportions, as will be seen from the subjoined analysis by VARRENTRAPP:—

	Analyses of ashes of brown coal from Brunswick, represented centesimally.
Lime,..............................	23·67
Magnesia, ...	2·58
Alumina,............................	11·57
Oxide of iron,.......................	5·78
Carbonate of potassa,................	2·64
Silica and clay, ...	19·27
Sulphuric acid,......................	33·83
Loss, ...	0·66
	100·00

Lead, copper, iron pyrites, and traces of iodine, *et cetera*, are also found in coal, but are by no means general. In fact, the traces of lead and copper are sometimes so minute as not to admit of estimation; but this is not the case with the iron pyrites. In some varieties this compound may be readily distinguished in clusters of cubic crystals, or in seams running through the mass; and, from its characteristic yellow appearance, the coals in which it is thus found are named *brassy coals*. It operates more injuriously than any of the other mineral compounds, as, during the combustion, the sulphur is transformed into sulphurous acid, which in itself is poisonous; and although it passes off considerably diluted by the other gases produced, yet it is hurtful, not only to animal life, but to many manufacturing processes, as well as to the boilers and furnaces of locomotives. When sulphurous coals are distilled, one-half or a certain portion of the sulphur is eliminated in the form of sulphide of hydrogen and sulphide of carbon, whilst the remainder is left united with the metallic base in the coke. In both cases it is the cause of much trouble and injury, as every gas manufacturer and smelter well knows. But these are not the only evils resulting from the iron pyrites. When coals containing it in large quantities are stored, and are affected with moisture, it not unfrequently happens that spontaneous ignition sets in, in consequence of the bisulphide being converted by its oxidation into sulphate of iron, and generating at the same time as much caloric as determines the combustion of the carbonaceous matter, which ultimately may reach to a red heat. To guard against this danger, it is well to expose the heap as much as possible to a current of air, in order that the moisture may spontaneously pass off, and the entire mass be kept cool; or, if incipient combustion has already set in, it may be arrested by loosening and turning over the heap, so that the air may pass through it freely. This spontaneous combustion is more apt to take place in mines than in the coals even when stored, unless, indeed, they are accumulated in confined places where the temperature is somewhat elevated. Under such circumstances, aided by the presence of moisture, the coals are very liable to burn voluntarily. Although the combustion which has been going on in some mines for considerable periods, cannot be attributed to the oxidation of the pyrites, but rather to the large volumes of inflammable gases which are generated in crevices in the mass, and which are accidentally ignited, yet it cannot be doubted that, through the combined action of water and a limited supply of air, the mineral assists in developing the heat throughout. When a mine takes fire, it resists every effort to extinguish it, unless the whole working be so regulated as to admit of being flooded with water. This, however, is rarely the case, nor is it ever thought of as a provision for such an emergency; and yet it is the only effective precaution that can be adopted, for the numerous fissures in the coal, which often extend to the surface, serve the purpose of powerful chimneys, whilst other chinks cooperate with the shafts, in conveying air to the seat of the fire. Every exertion has been made to check the combustion going on in some of the British mines by the erection of dams; but, although it is believed that in some of them the rate of consumption is much reduced, it still continues.

Although the specific gravity of coals and the per centage of ash which they contain are very insufficient tests of their value as fuel, yet it is evidently important to know the amount of the combustible constituents in different kinds. Fortunately, numerous analyses of coals have been made; and the Editor feels assured that a summary and compendious view of the most important of these cannot fail to be deeply interesting to all who are concerned in those arts and manufactures in which fuel is an object of primary consideration, as well as to the scientific analyst. Accordingly, the following tables exhibit the results so elaborately worked out for the Admiralty by Dr. LYON PLAYFAIR, and others, in their examination of nearly all the products of the British coal mines:—

MEAN COMPOSITION OF AVERAGE SAMPLES OF WELSH COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Aberaman Merthyr,	1·305	90·94	4·28	1·21	1·18	0·94	1·45	85·0
Ebbw Vale,	1·275	89·78	5·15	2·16	1·02	0·39	1·50	77·5
Thomas's Merthyr,	1·30	90·12	4·33	1·00	0·85	2·02	1·68	86·53
Duffryn,	1·326	88·26	4·66	1·45	1·77	0·60	3·26	84·3
Nixon's Merthyr,	1·31	90·27	4·12	0·63	1·29	2·53	1·25	79·11
Binea,	1·304	88·66	4·63	1·43	0·33	1·03	3·96	88·10
Bedwas,	1·32	80·61	6·01	1·44	3·50	1·50	6·94	71·7
Hill's Plymouth Work,	1·35	88·49	4·00	0·46	0·84	3·82	2·39	82·25
Aberdare Co.'s Merthyr,	1·31	88·28	4·24	1·66	0·91	1·65	3·26	85·83
Gadly Nine-feet Seam,	1·33	86·18	4·31	1·09	0·87	2·21	5·34	86·54
Resolven,	1·32	79·33	4·75	1·38	5·07	included in ash.	9·41	83·9
Mynydd Newydd,	1·31	84·71	5·76	1·56	1·21	3·52	3·24	74·8
Aberearn,	1·334	81·26	6·31	0·77	1·86	9·76	2·04	68·4
Anthracite, Jones and Co.,	1·375	91·44	3·46	0·21	0·79	2·58	1 52	92·9
Ward's Fiery Vein,	1·344	87·87	3·93	2·02	0·83	Included in ash.	7·04	—
Neath Abbey,	1·31	89·04	5·05	1·07	1·60	—	3·55	61·42
Graigola,	1·30	84·87	3·84	0·41	0·45	7·19	3·24	85·5
Gadly Four-feet Seam,	1·32	88·56	4·79	0·88	1·21	—	4·88	88·23
Machen Rock Vein,	1·297	71·08	4·88	0·95	1·37	17·87	3·85	65·2
Birch Grove, Graigola,	1·360	84·25	4·15	0·73	0·86	5·58	4·43	85·1
Llynvi,	1·28	87·18	5·06	0·86	1·33	2·53	3·04	72·94
Cadoxton,	1·378	87·71	4·34	1·05	1·75	1·58	3·57	82·0
Oldcastle Fiery Vein,	1·289	87·68	4·89	1·31	0·09	3·39	2·64	79·8
Vivian and Sons' Merthyr,	1·299	82·75	5·31	1·04	0·95	4·64	5·31	67·1
Llangennech,	1·312	85·46	4·20	1·07	0·29	2·44	6·54	83·69
Three-quarter Rock Vein,	1·34	75·15	4·93	1·07	2·85	5·04	10·96	62·5
Pentrepoth,	1·31	88·72	4·50	0·18	—	3.24	3·36	82·5
Cwn Frood Rock Vein,	1·255	82·25	5·84	1·11	1·22	3·58	6·00	68·8
Cwm Nanty Gros,	1·28	78·36	5·59	1·86	3·01	5·58	5·60	65·6
Brymbo Main,	1·300	77·87	5·09	0·57	2·73	9·52	4·22	55·4
Tivian and Sons' Rock Vawr,	1·301	79·09	5·20	0·66	2·41	8·34	4·30	58·6
Coleshill,	1·29	73·84	5·14	1·47	2·34	8·29	8·92	56·0
Brymbo Two-yard,	1·283	78·13	5·53	0·54	1·88	8·02	5·90	56·2
Rock Vawr,	1·29	77·98	4·39	0·57	0·96	8·55	7·55	62·50
Porth-mawr,	1·39	74·70	4·79	1.28	0·91	3·60	14·72	63·1
Pontypool,	1·32	80·70	5·66	1·35	2·39	4·38	5·52	64·8
Pentrefelin,	1·358	85·52	3·72	trace	0·12	4·55	6·09	85·0

MEAN COMPOSITION OF AVERAGE SAMPLES OF NEWCASTLE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Willington,	—	86·81	4·96	1·05	0·88	5·22	1·08	72·19
Andrew's House, Tanfield,	1·26	85·58	5·31	1·26	1·32	4·39	2·14	65·13
Bowden Close,	—	84·92	4·53	0·96	0·65	6·66	2·28	69·69
Haswell Wallsend,	1·286	83·47	6·68	1·42	0·06	8·17	0·20	62·70
Newcastle Hartley,	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
Hedley's Hartley,	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
Bates' West Hartley,	1·25	80·61	5·26	1·52	1·85	6·51	4·25	—
West Hartley Main,	1·264	81·85	5·29	1·69	1·13	7·53	2·51	59·20
Buddle's West Hartley,	1·23	80·75	5·04	1·46	1·04	7·86	3·85	—
Hastings' Hartley,	1·25	82·24	5·42	1·61	1·35	6·44	2·94	35·60
Carr's Hartley,	1·25	79·83	5·11	1·17	0·82	7·86	5·21	60·63
Davison's West Hartley,	1·25	83·26	5·31	1·72	1·38	2·50	5·84	59·49
North Percy Hartley,	1·25	80 03	5·08	0·98	0·78	9·91	3·22	57·18
Haswell Coal Co.'s Steamboat Wallsend,	1·27	83·71	5·30	1·06	1·21	2·79	5·93	61·38
Derwentwater Hartley,	1·26	78·01	4·74	1·84	1·37	10·31	3·73	54·83
Broomhill,	1·25	81·70	6·17	1·84	2·85	4·37	3·07	59·20
Original Hartley,	1·25	81·18	5.56	0·72	1·44	8·03	3·07	58·22
Cowpen & Sidney's Hartley,	1·26	82·20	5·10	1·69	0·71	7·97	2·33	58·59

MEAN COMPOSITION OF AVERAGE SAMPLES OF DERBYSHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal
	A.	B.	C.	D.	E.	F.	G.	H.
Earl Fitzwilliam's Elsecar,	1·296	81·93	4·85	1·27	0·91	8·58	2·46	61·6
Holyland and Co.'s Elsecar,	1·317	80·05	4·93	1·24	1·06	8·99	3·73	62·5
Earl Fitzwilliam's Park Gate,	1·311	80·07	4·92	2·15	1·11	9·95	1·80	61·7
Butterly Co.'s Portland,	1·301	80·41	4·65	1·59	0·86	11·26	1·23	60·9
Butterly Co.'s Langley,	1·264	77·97	5·58	0·80	1·14	9·86	4·65	54·9
Stavely,	1·27	79·85	4·84	1·23	0·72	10·96	2·40	57·86
Loscoe Soft,	1·285	77·49	4·86	1·64	1·30	12·41	2·30	52·8

MEAN COMPOSITION OF AVERAGE SAMPLES OF LANCASHIRE COALS.

Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Inch Hall Co.'s Arley,	1·272	82·61	5·86	1·76	0·80	7·44	1·53	64·0
Haydock Little Delf,	1·257	79·71	5·16	0·54	0·52	10·65	3·42	58·1
Balcarres Arley,	1·26	83·54	5·24	0·98	1·05	5·87	3·32	62·89
Blackley Hurst,	1·26	82·01	5·55	1·68	1·43	5·28	4·05	57·84
Ince Hall, Pemberton Yard,	1·348	80·78	6·23	1·30	1·82	7·53	2·34	60·6
Haydock, Rushy Park,	1·323	77·65	5·53	0·50	1·73	10·91	3·68	59·4
Moss Hall, Pemberton, Four-feet,	1·258	75·53	4·82	2·05	3·04	7·98	6·58	55·7
Haydock Higher, Florida,	1·218	77·33	5·56	1·01	1·03	12·02	3·05	51·1
Ince Hall, Pemberton, Four-feet,	1·276	77·01	3·93	1·40	1·05	5·52	1·09	57·1
Blackbrook Little Delf,	1·26	82·70	5·55	1·48	1·07	4·89	4·31	58·48
King,	1·300	73·66	5·30	1·68	1·58	9·06	8·72	62·4
Rushy Park Mine,	1·28	77·76	5·23	1·32	1·01	8·99	5·69	56·66
Blackbrook, Rushy Park,	1·27	81·16	5·99	1·35	1·62	7·20	2·68	58·10
Johnson and Wirthington's, Rushy Park,	1·28	79·50	5·15	1·21	2·71	9·24	2·19	57·52
Laffak, Rushy Park,	1·35	80·47	5·72	1·27	1·39	8·33	2·82	56·26
Balcarres, Haigh Yard,	1·28	82·26	5·47	1·25	1·48	5·64	3·90	66·09
Haydock, Florida Main,	1·267	77·49	5·50	1·27	0·88	12·84	2·02	54·4
Wigan, Four-feet,	1·209	78·86	5·29	0·86	1·19	9·57	4·23	60·0
Ince Hall, Pemberton, Five-feet,	1·269	68·72	4·76	2·20	1·35	18·63	14·34	56·5
Cannel—Wigan,	1·23	79·23	6·08	1·18	1·43	7·24	4·84	60·33
Ince Hall Co.'s Furnace Vein,	1·314	74·74	5·71	1·53	0·96	13·52	4·04	58·4
Balcarres, Lindsay,	1·26	83·90	5·66	1·40	1·51	5·53	2·00	57·84
Caldwell and Thompson's, Rushy Park,	1·271	76·17	5·46	1·09	0·91	14·87	1·50	58·7
Barcarres, Five-feet,	1·26	74·21	5·03	0·77	2·09	8·69	9·21	55·90
Moss Hall, Pemberton, Five-feet,	1·283	76·16	5·35	1·29	1·05	10·13	6·02	56·1
Moss Hall Co.'s New Mine,	1·278	77·50	5·84	0·98	1·36	12·16	3·16	57·7
Caldwell and Thompson's Higher Delf,	1·274	75·40	4·83	1·41	2·43	19·98	5·95	54·2
Johnson and Wirthington's Sir John,	1·31	72·86	4·98	1·07	1·54	8·15	11·40	56·15

MEAN COMPOSITION OF AVERAGE SAMPLES OF SCOTCH AND VARIOUS OTHER COALS.

	Locality, or Name of Coal.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Percentage of Coke left by each Coal.
		A.	B.	C.	D.	E.	F.	G.	H.
Scotch Coals.	Wallsend Elgin,	1·20	76·09	5·22	1·41	1·53	5·05	10·70	58·45
	Wellewood,	1·27	81·36	6·28	1·53	1·57	6·37	2·89	59·15
	Dalkeith Coronation Seam,	1·316	76·94	5·20	trace.	0·38	14·37	3·10	53·5
	Kilmarnock Skerrington,	1·241	79·82	5·82	0·94	0·86	11·31	1·25	49·3
	Fordel Splint,	1·23	79·58	5·50	1·13	1·46	8·33	4·00	52·03
	Grangemouth,	1·29	79·85	5·28	1·35	1·42	8·58	3·52	56·6
	Eglinton,	1·25	80·08	6·50	1·55	1·38	8·05	2·44	54·94
	Dalkeith Jewel Seam,	1·277	74·55	5·14	0·10	0·33	15·51	4·37	49·8
Various.	Coleshill Co.'s Bagilt Main,	1·269	88·48	5·62	2·02	1·36	0·86	1·62	55·8
	Ewlowe,	1·275	80·97	4·96	1·10	1·40	8·20	3·37	54·5
	Ibstock,	1·291	74·97	4·83	0·88	1·45	11·88	5·99	50·8

AVERAGE COMPOSITION OF COALS FROM DIFFERENT LOCALITIES.

Locality.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen	Ash.	Percentage of Coke left by each Coal.
	A.	B.	C.	D.	E.	F.	G.	H.
Average of 36 samples from Wales,	1·315	83·78	4·79	0·98	1·43	4·15	4·91	72·60
" 18 " Newcastle,	1·256	82·12	5·31	1·35	1·21	5·69	3·77	60·67
" 28 " Lancashire,	1·273	77·90	5·32	1·30	1·44	9·53	4·88	60·22
" 8 " Scotland,	1·259	78·53	5·61	1·00	1·11	9·69	4·03	54·22
" 7 " Derbyshire,	1·292	79·68	4·94	1·41	1·01	10·28	2·65	59·32

AVERAGE COMPOSITION OF FOREIGN COALS.

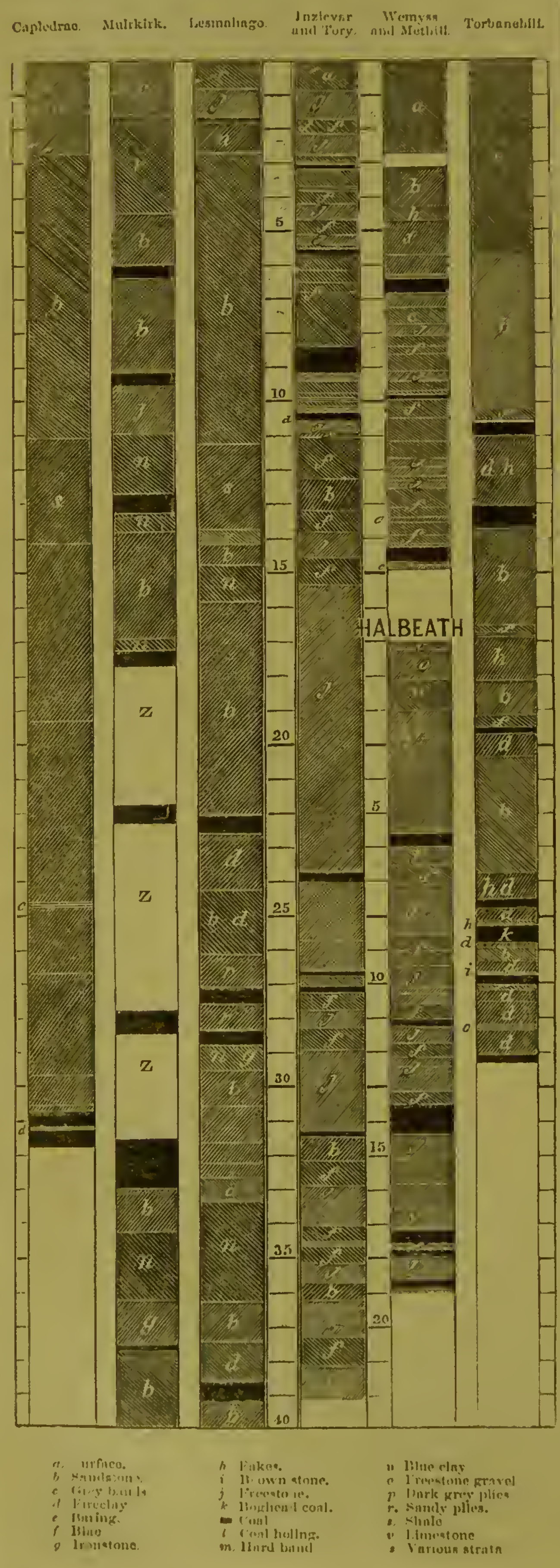
	Locality.	Specific Gravity of Coal	Carbon.	Hydrogen	Nitrogen	Sulphur	Oxygen	Ash
		A.	B.	C.	D.	E.	F.	G.
Van Diemen's Land Coals.	South Cape,	—	63·40	2·89	1·27	0·98	1·01	30·45
	Mount Nicholas Break o'Day,	—	57·37	3·91	1·15	0·90	9·10	27·55
	Tingal,	—	57·21	3·38	1·20	1·32	7·80	29·09
	Jerusalem,	—	68·18	3·99	1·62	1·12	[illegible]	19·29
	Douglas River, East Coast,	—	70·44	4·20	1·11	0·70	9·27	14·28
	Tasman's Peninsula,	—	65·54	3·36	1·91	1·03	1·75	26·41
	Schonten Island,	—	64·01	3·55	0·94	0·85	3·38	27·17
	Whale's Head, South Cape,	—	65·86	3·18	1·12	1·14	7·20	21·50
	Adventure Bay,	—	80·22	3·05	1·26	1·90	4·80	8·77
	Sydney, New South Wales,	—	82·39	5·32	1·23	0·70	8·32	2·04
	Borneo—Lahman Kind,	1·28	64·52	4·74	0·80	1·45	20·75	7·74
	" Three-feet Seam,	1·37	54·31	5·03	0·98	1·14	24·22	14·32
	" Eleven-feet Seam,	1·21	70·33	5·41	0·67	1·17	19·19	3·23
	Formosa Island,	1·24	78·26	5·70	0·64	0·49	10·25	[illegible]
	Vancouver's,	—	66·93	5·32	1·02	2·20	8·70	15·83
	Lignite, Trinidad,	—	65·20	4·25	1·33	0·69	21·69	6·84
Chili Coals.	Conception Bay,	1·29	70·55	5·76	0·95	1·98	13·24	7·52
	Port Famine,	—	64·18	5·33	0·50	1·03	22·75	6·21
	Chirique,	—	38·98	4·01	0·58	6·14	13·38	36·91
	Laredo Bay,	—	58·67	5·52	0·71	1·14	17·33	16·63
	Talcahnano Bay,	—	70·71	6·44	1·08	0·94	13·95	6·92
	Colcurra Bay,	—	78·30	5·50	1·09	1·06	8·37	5·68
Patagonia Coals.	Sandy Bay, No. 1,	—	62·25	5·05	0·63	1·13	17·54	13·40
	" No. 2,	—	59·63	5·68	0·64	0·96	17·45	15·64

Having seen in the foregoing the ultimate constituents of the several varieties examined, and also the amount of coke which they afford when heated in close vessels, the next point that demands inquiry is the state or condition in which those elements are contained in the coal. It is the belief of many, that common coal is compounded of a carbonaceous substance like anthracite, and a bituminous one; and it would appear, from the microscopical researches which have been made, that such is usually the case. When, however, the fusibility of good coal is considered, and the homogeneous mass which it yields upon exposure to heat is closely examined, one is led to infer that the carbon is not isolated, but combined with the other constituents in such a manner as to form a definite body. Doubtless, in some species of lignite, the bituminous matter is partly distinct from the carbonaceous; this may be deduced from the considerable quantity of tar which they yield, and the friable porous nature of their coke. From many facts connected with the manufacture of gas and other products from coal, it must be evident that this substance is chiefly composed of various carbides of hydrogen, which suffer decomposition by heat, and which, from the circumstance that suitable solvents have not yet been discovered, remain unisolated. It is an authenticated fact, that the more the amount of hydrogen in a coal exceeds that of the oxygen, the more fusible is the substance, and *vice versa*; but this surplus is not sufficient to account for its fusibility; the entire quantity is concerned in producing the effect. When the amount of hydrogen is small, the coal will not be so fusible as when the proportion is larger, although, in the first case, the ratio in which it stands to the oxygen may be much greater than in the second. If the absolute per centage of hydrogen is only about two, there is little reason to expect that such a coal will undergo fusion when submitted to heat. Experiments have shown that it requires at least three per cent. of hydrogen in the substance, with as much oxygen as will combine with half of this to form water, to render it fusible under the influence of caloric. Such a coal affords a very intumescent coke. Coals less inclined to melt than one so constituted, may contain a variable amount of hydrogen; but when the proportion exceeds one-and-a-half per cent., the oxygen will be required in quantities capable of transforming at least two-thirds of this into water. On the other hand, if the hydrogen and oxygen be exactly so proportioned in the coal as to form water, the coal will be infusible, and the coke which is left will be pulverulent. It is remarkable that many substances constituted of carbon, hydrogen, and oxygen, differ in this particular from coals; thus sugar, gums, starch, when submitted to heat, fuse, and yield a compact coke. Hence it may be inferred that whether an organic matter containing about forty-eight per cent. of carbon, with oxygen and hydrogen to constitute water, shall be fusible or not depends on circumstances still requiring explanation. When the quantity of carbon exceeds fifty per cent., the substance is or is not fusible, according as the amount of hydrogen is or is not in excess above that which is necessary to convert the oxygen into water. All woody and fibrous matters are infusible, owing to their content of carbon being more than fifty per cent., whilst the oxygen and hydrogen making up the remainder are so proportioned as to compose water; there are, however, other bodies in which the carbon constitutes from half to nine-tenths of their weight, and yet they are fusible and even volatile under the influence of heat. Such is the case with some of the resins, wax, *et cetera*, which contain a large quantity of hydrogen that assimilates itself with the carbon, giving rise either to gaseous bodies, or liquids, into which the latter largely enters. It is upon these grounds also that the explanation of the fusion of coals so rich in carbon as eighty per cent. rests.

In many branches of trade, experience has pointed out the advantages which some varieties of coals afford, from the circumstance that the nature of their combustion is adapted to the special work assigned them. Hence the selection of gas coal, steam coal, and such like, on account of the respective qualities they possess; the former of producing large quantities of gas, the latter of yielding a high temperature, at the same time that its combustion is tardy and gradual. The first are evidently such as, when heated, enter more into fusion, as is obvious from the adoption of cannel in gas-works whenever it can be found. For generating steam, coals which are only slightly fusible, and bordering upon the nature of anthracite, are found from experience to be the best. For various other manufacturing purposes, the particular requirements of each must decide the fittest quality of fuel. In reverberatory furnaces, and such others as are constructed with the view of producing an effect at a distance from the fire, flaming coals will be found best adapted for the purpose, but not those which are apt to form a coherent cake in the grate, whereby the draught would be impeded, and the combustion be inadequate to the effect required. On the other hand, where the heat must be very intense, those coals are found to be the best which contain a large per centage of carbon, with enough hydrogen and oxygen as will generate sufficient quantities of inflammable gases to promote its rapid ignition, but at the same time not so much as will effect fusion to any considerable extent. Such is the kind required in the smelting of metals, for the working of iron, *et cetera*. This subject will be further explained when the values of fuel come under consideration.

Torbanehill, or Boghead Coal.—The peculiar characters of this substance, on the nature of which geologists and chemists were much divided, attracted very great attention several years ago, and led to important legal proceedings, arising out of the following circumstances. In the beginning of the year 1850, a contract of lease was entered into between the proprietor of the estate of Torbanehill, near Bathgate, Linlithgowshire, and the Messrs. Russel, Falkirk, conveying to the latter, in consideration of a fixed rent, a right to the whole coal, ironstone, iron ore, limestone, and fire-clay, on the lands of Torbanehill, for a period of twenty-five years; but the lease was not to comprehend copper, or *any other mineral whatever except those above specified.* In the course of their researches, the Messrs. Russel had previously found an extensive deposit of the Torbanehill coal, which was shown by Dr. Penny, in 1849, to be invaluable as a coal for the manufacture of gas. As such, it was worked and disposed of by the Messrs. Russel, to whom, at the very small rent at which their right to the minerals was acceded, it promised to be a source of large revenue. In these circumstances, the proprietor of Torbanehill brought an action against the lessees for damages, laid at £10,000, on the ground that the substance was not coal at all, nor any of the minerals comprehended in the lease, and that, therefore, the lessees had no right to remove it. The case was tried at Edinburgh, before the Lord Justice-General and a special Jury, in the months of July and August, 1853, and excited intense interest, both on account of the curious scientific question involved, and the number of eminent scientific authorities cited on both sides as witnesses. The apparently conflicting character of their testimony was also somewhat remarkable. Professor Ansted, for instance, did not give the substance any name at all; Professor Brande said it was a new peculiar mineral; Professor Chapman had no hesitation in pronouncing it a bituminous shale; the late Mr. Hugh Miller characterized it as the most inflammable shale he had ever seen. Professor Anderson said it was not a bituminous shale, whatever it was. Dr. Wilson said he would call it a clay impregnated with bituminous matter, and Mr. Milne, in like manner, called it a clay bituminated. On the other hand, Dr. Fleming of Edinburgh, Professor Graham, Dr. John Stenhouse, Professor Johnston, Dr. Penny, Dr. Hoffman, Dr. Frankland, and other equally eminent authorities, pronounced it unquestionably a coal. At the same time, the only material difference, with reference to the facts of the case, appeared in the results of the microscopical examination. The geologists and chemists agreed as to the constitution of the substance—they differed only in the name which they were inclined to give it, according to their special views of what constituted coal; but not so the microscopists, three of whom were examined for the pursuer, and four for the defenders. Of these gentlemen, the former agreed in asserting that there was no trace of organic structure, no woody fibre or tissue—in short, no trace of vegetal matter in the substance under consideration; on the other hand, the defenders' witnesses affirmed that in every part of it there was the clearest evidence of vegetal structure; and three of these gentlemen were skilful botanists, whilst those examined for the pursuer did not lay claim to that character. Even the microscopical evidence, therefore, was strongly in favor of the claim of the Torbanehill mineral to be considered a true coal; and this, in concurrence with the general analogies presented, induced the jury to return a verdict for the defenders. In this verdict—which quite harmonized with the opinion pronounced by Dr. Penny before the Torbanehill coal became a subject of litigation at all—there seems to be no difficulty in acquiescing. Among the recognized true coals, there are infinite diversities in the relative proportion of the ingredients—from anthracite at one end of the scale, to cannel or parrot coal at the other; and the Torbanehill coal appears, from its composition, to be not less justly entitled to the name of a coal than anthracite, though standing at the opposite end of the scale.

In all its leading physical and chemical characters, it is identical with other varieties of cannel coal. It is unquestionably of vegetal origin. It forms a seam varying in thickness from sixteen to twenty-one inches. Its geological position does not differ from that of other Scotch cannel coals, and the associated rocks are similar to those that occur in other coal fields. In the upper part of the seam the color of this coal is brown, and the streak light yellowish-brown; but in the lower part its color is black. Fossil plants, especially stigmaria of various sizes, and with numerous rootlets, are found in every part of the coal. Some are in the shape of large trunks of trees, one or two feet in diameter. The impressions of scalariform vegetal tissue are also exhibited in almost every fractured surface. The following section of the cannel coal-fields of Scotland, by Mr. John Geddes of Edinburgh, shows the relative position of the coal, and its depth in fathoms from the surface:—



The color of this coal varies from dark snuff-brown to dull brownish-black; streak light brown; powder dull olive brown-black. It does not soil the fingers; it adheres to the tongue, and it has, when moistened, the odor of clay. It is exceedingly hard, and very difficult to break in a direction perpendicular to the plane of stratification. It is distinctly laminated, and the large rhomboidal blocks, as brought from the pit's mouth, may be readily split into thin slabs, less than an inch in thickness. Its fracture is slaty, and often beautifully conchoidal. When struck with a hammer, it gives a distinct and deep woody sound. Does not become electrical by friction. Specific gravity varies from 1·155 to 1·260; average about 1·1892.

Its microscopical characters have been ably discussed by Professor Redfern, in the third volume of the *Quarterly Journal of the Microscopical Society.*

It readily ignites, and burns with a bright, voluminous, and smoky flame. In the open fire it splits, and crackles like other cannel coals. It does not intumesce or melt. When completely burned, it leaves a considerable quantity of fine white ash, amounting on the average to twenty-one per cent. Several cannel coals give a larger quantity of ash—page 85. The ash contains, in 100 parts:—Silica, 56·0; alumina, 43·52; oxide of iron, 0·35; potash, 0·4; soda, 0·36; with traces of lime, magnesia, phosphoric acid, chlorine, and sulphuric acid. Herapath has proposed to use the ash in the manufacture of alum. This coal is not appreciably acted upon by ether, bisulphide of carbon, benzol, oil of turpentine, or naphtha. When distilled in the usual manner, it gives the same products as other cannel coals—namely, gaseous hydrocarbons, tar, paraffin, paraffin-oil, naphtha, naphthalin, benzol, ammonia, *et cetera.*

It contains every ingredient found in other varieties of coal; and there is no substance in it that does not exist in other coals. The results of its elementary analysis by Dr. Penny, after being dried at 212°, are shown in the following statement:—

	With ash.	Without ash.
Carbon,	63·936	81·159
Hydrogen,	8·858	11·245
Nitrogen,	0·962	1·221
Sulphur,	0·320	0·406
Oxygen,	4·702	5·969
Ash,	21·222	—
	100·000	100·000

It yields about 67·0 per cent. of volatile matter, and 1·7 of coke. Different specimens, however, vary onsiderably in this respect, as shown in the following ble, which exhibits the results of the analysis of four pecimens taken from the pit at different dates:—

	Brown.		Black.	
	1849.	1851.	1851.	1853.
Volatile matters,	71·0	71·0	62·70	67·11
Fixed carbon,	11·3	7·1	9·25	10·52
Ash,	16·8	21·2	26·50	21·0
Sulphur,	0·3	0·2	0·35	0·32
Water,	0·6	0 5	1·20	1·05
	100·0	100·0	100·00	100·00
Coke,	28·1	28·3	35·75	31·52
Specific gravity,	1·1550	1·160	1·2185	1·1882

In its chemical composition this coal is characterised by containing more hydrogen than any other variety, and by giving less fixed carbon and more ash than most other coals. Its coke, which is valueless as fuel, contains 33·4 per cent. of carbon and hydrogen, and 66·6 per cent. of ash. It surpasses all other cannel coals in its gas-producing powers. It yields from thirteen thousand to fifteen thousand cubic feet per ton, whereas the best qualities of other coals give from eleven thousand to twelve thousand cubic feet. The gas produced from it is extremely rich in hydrocarbons, which burn with flame possessing a high degree of luminosity; hence this coal is admirably suited to be mixed with inferior varieties of cannel coal in the manufacture of gas. When distilled at comparatively low temperatures, it affords large quantities of paraffin, paraffin-oil, *et cetera*, a discovery made and patented a few years ago by Mr. Young. Several interesting products have recently been obtained from it by Greville Williams.

The following table will be found useful:—

MEAN COMPOSITION OF VARIOUS SCOTCH CANNEL COALS, ANALYSED BY DR. PENNY OF GLASGOW.

Locality or Name of Coal.	Specific gravity.	Volatile matters.	Fixed carbon.	Ash.	Sulphur.	Water.	Coke.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Rochsoles—1851,	1·448	53·7	4·9	38·8	1·6	1·0	43·70
2. Hardie's—1852,	1·420	34·0	4·0	58·4	*	3·6	62·40
3. Boghead, *Brown*—1851,	1·160	71·06	7·10	21·2	0·24	0·4	28·30
4. Boghead, *Black*—1851.	1·2185	62·7	9·25	26·5	0·35	1·2	35·75
5. Torbanehill—1853,	1·1892	67·11	10·52	21·0	0·32	1·05	31·52
6. Boghead—1849,	1·1550	71·3	11·3	16·8	(·34)	0·6	28·10
7. Bathville,	1·201	64·35	12·6	22·2	0·25	0·60	34·80
8. Stand—Airdrie,	1·4647	52·08	14·77	32·0	*	1·15	46·77
9. Methill,	1·3002	49·23	17·57	29·7	*	3·50	47·27
10. Capeldrae,	1·3603	45·73	19·97	31·5	*	2·80	51·47
11. Wemyss,	1·1831	58·52	25·28	14·25	*	1·95	39·53
12. Balbardie--1852,	1·420	38·96	29·66	28·0	0·38	3·0	57·66
13. Hillhead—Kilmarnock,	1·602 1·320	36·65	32·34	27·4	0·61	3·0	59·74
14. Brymbo,	*	32·10	36·4	29·4	*	2·1	65·80
15. Lesmahagow—Auchinheath,	1·1990	56·23	36·7	4·3	0·55	2·22	41·00
16. Bartonshill,	1·280	46·0	39·6	10·0	2·0	2·4	49·60
17. Bartonshill,	1·350	38·0	37·9	18·7	2·2	3·2	56·60
18. Stevenson—Ayrshire,	1·3850	40·21	40·14	19·35	*	0·3	59·49
19. Lesmahagow—Southfield,	1·228	49·34	40·97	6·34	1·35	2·0	47·31
20. Knightswood,	1·234	44 77	41·13	11·05	*	3·05	52·18
21. Cairnbroe,	1·247	42·83	42·67	8·50	*	6·0	51·17
22. Skaterigg,	1·252	49·32	44·83	2·50	*	3·35	47·33
23. Cowdenhill,	1·299	46·0	45·0	5·0	0·50	3·50	50·00
24. Breadisholme,	1·335	39·0	48·5	8·1	0·4	4·0	56·60
25. Ruchill,	1·223	45·73	49·27	2·5	*	2·5	51·77
26. Kelvinside,	1·231	40·17	53·42	1·9	0·21	4·3	55·32

* Not estimated.

Coke.—Like wood and peat, coal has been found unadapted for many purposes in its natural state; either the heat which it evolves is insufficient from the presence of water and other ingredients, or the same effect is produced by the tendency of most coals to fuse and form a coherent mass, whereby the air is excluded, and the combustion impeded. Although the latter is the most frequent cause of failure, both contribute to render coals inapplicable to the wants of many of the arts and manufactures. To obviate these difficulties, and to bring the coal to a state in which it will yield the greatest possible amount of heat, recourse has been had to carbonization, the idea being borrowed, doubtless, from the advantage gained by a similar treatment of wood. By this operation, the principles of which have been already explained, the volatile products are expelled, and the liquid bodies decomposed, so that their carbon becomes to a great extent fixed, whilst the hydrogen and oxygen are dispersed. These volatile matters are utilized or not, according to the circumstances and the locality in which the carbonization is carried on. Thus, when the operation is conducted in large towns, the gases become not only a source of profit to the persons engaged in the trade, but of comfort and safety to society by their illuminating power. In localities which are not populous, or which are far removed from cities and towns, these valuable products are permitted to pass off, not only uselessly, but often injuriously to animal and vegetal life. In either case, the fixed matter left is known as coal-charcoal or coke.

The charring of coals is conducted under these circumstances with very different objects. In towns, the coke is, in fact, only a secondary product, and is little regarded in comparison to the volatile matters, whilst in those places where the coal is burned on the field for the smelters and for locomotive purposes, all the value is attached to the solid body remaining. These latter—the iron trade and steam locomotion—are the principal sources of consumption of this kind of fuel; and since the introduction of both upon an extended scale, the inventive genius of scientific men has been exercised to discover methods of carbonizing the coal, not only more rapid in action, but also more effective, and calculated to produce a substance as much as possible divested of the volatile bodies which diminish its heating power. It could scarcely be expected that a subject so interesting as this, so important to many branches of manufacturing industry, and consequently so well meriting the attention of intelligent scientific and practical men, could long rest without eliciting many suggestions towards improvement. How far these have been attended with success, will appear in the following pages.

Adopting the same arrangement as in former cases, it may be well to say a few words, in the first place, on the charring or coking properties of *brown coal*, which is sometimes employed for this purpose. In Great Britain, where bituminous and stone coal abound to the extent already stated, and where the presence of lignite is very partial, the latter is carbonized with the view of rendering it more useful—a practice, however, restricted to those places where the more perfect coal is scarce. Where such conditions exist, the charring of lignite—a work which is difficult and troublesome to effect—is repaid with very indifferent results. This arises from its peculiar property of splitting asunder as the heat enters, and hence the mass when charred is little else than a heap of small fragments which are unsuited for those works requiring the use of a compact coke. It is stated by ROSCHERS, that lignite, if thoroughly dried in the air immediately after it is taken from the pit, and then slowly charred, affords a charcoal possessing considerable cohesive properties; and MAYER, in like manner, affirms that the inconvenience may be obviated by subjecting the coal to slow carbonization after it is taken from the mine. The methods usually adopted are similar to those already described for the charring of wood and peat; but the yield from this species of coal is so small, that the labor bestowed upon the operation is hardly repaid. In the German works, where lignites have been charred, the per centage of charcoal by weight averaged from fifteen to eighteen per cent., and by volume from about thirty-two to thirty-five; but this quantity is much below that obtained on a small scale, when the carbonizers used are close crucibles.

The annexed table gives a synopsis of the per centage which various lignites afforded by this treatment:—

		Per cent of charcoal.
	Earthy coal from Dax,	49·1
	" " Bouch-d-R.,	41·1
	" " Basses-Alpes,	48·5
	Lignite from Greece,	39·8
	" Cologne,	36·1
	" Iceland,	57·0
Left side of the Rhine, near Düren.	" Raddergrube,	41·6
	" "	49·7
	" Grube Urwelt,	44·3
	" "	43·9
	" "	51·3
	" Friesdorf,	28·2
	" "	48·2
	" "	46·8
	Earthy coal from Utterweiler,	68·2
	" Raddergrube,	48·3
	" "	46·4
Right side, near Bonn.	Lignite from Püitzchen,	46·4
	" "	44·7
	" "	51·0
	" Stösschen,	29·1
	" "	40·6
	" Orsberg,	62·8
	" "	68·4
Bohemia.	" Aussig,	40·1
	" "	40·0
	" Hegendorf,	41·2
	" Neundorf,	38·4
	" Coulang,	38·1

		Per cent of charcoal.
Bohemia.	Lignite from Jahnsdorf,	32·8
	" Paredel, 1	3[illegible]·6
	" " 2	40·7
	" " 3	42·0
	" Antoni-Zeche,	40·0
	" Wellonitzer, Br.	35·9
	" Nempschater, Br.	34·7
	" Hartenberg, 1	37·2
	" " 2	34·6
	" Kanden,	37·5
	Pitch coal from Grünlat,	37·2
	Earthy coal from Hartenberg, 1	42·1
	" " 2	46·4
	" " 3	36·8
	" " 4	39·0
	Pitch coal from Hartenberg, 1	43·9
	" " 2	40·3
	Earthy coal from Joaz,	46·4
	Pitch coal from Reichenau,	35·1
	" "	29·3
	" Altsattel,	40·3
	" "	35·0
Bavarian Oberb-falz.	Earthy coal from Verau,	35·6
	Lignite,	46·0

The carbonization of lignite is a subject of but little interest to manufacturers, in consequence of its use being so very limited. The Editor will, therefore, proceed to the consideration of pit charcoal, which is of vast importance to every country aspiring to progress in civilization and manufacturing industry. More particularly is this the case as regards Great Britain; for the extent of her smelting establishments, and her vast application of steam power in locomotion, as well as in various manufactures, call forth every exertion to supply the most perfect source of heat which skill and science can provide. Not only do her own industrial wants demand this, but other countries, which are not so highly favored in the amount of fossil fuel at their command, make urgent calls upon her resources: and coals and coke are exported to a considerable extent to supply the railways and steam navigation of other states.

The extensive variety of coal met with necessarily suggests a corresponding difference in the effects produced by the action of heat upon them, and it is to be expected that the products should indicate similar differences. All coals which are in any degree bituminous, yield three classes of bodies—namely, the residuary matter, containing carbon in excess; the liquid substances, which are in like manner very carbonaceous; and the gaseous bodies, of which there are several. It is almost needless to remark, that the proportion of the second class will be dependent upon the fusibility of the coals; and even the third is chiefly derived from fusible or caking coals. As a general example of the nature and relative proportions of these three varieties of products, the following analysis may be taken:—

		Centesimally.
	Coke,	68·925
Liquid products.	Tar,	12·230
	Water,	7·569
Gaseous products.	Light carbide of hydrogen,	7·021
	Carbonic oxide,	1·135
	Carbonic acid,	1·073
	Olefiant gas,	0·753
	Sulphide of hydrogen,	0·549
	Hydrogen,	0·499
	Ammonia,	0·211
	Nitrogen,	0·035

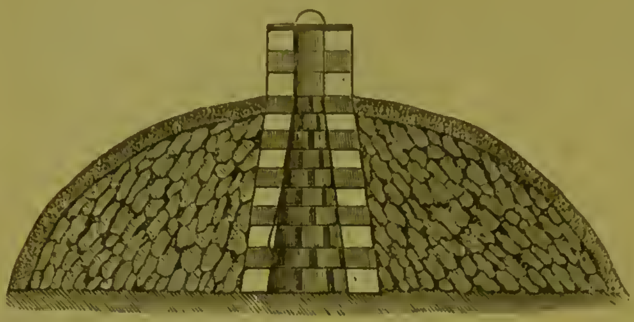
While the absolute and relative yield of these products depends chiefly on the composition of the coal, the method and management of the operation to which they are submitted exercises a marked influence. Thus it may be seen practically that the products differ to the extent of several units per cent., according as the heat applied in the charring is low and gradual, or elevated and rapid. In the amount of coke, which constitutes by much the largest product, or more correctly, the residue, the observed variation from this cause is sometimes so high as six per cent., but generally it ranges from three to four per cent. It is not only in quantity, however, that the mode in which the heat is applied produces a marked effect, the quality is liable to not less variation from the same cause. By the application of a low prolonged heat, gradually raised till it reaches the strongest red heat towards the completion of the carbonization, the coke is more compact, from the circumstance that the fusion of the coal is more perfect under the gradually increasing temperature, than if the latter were applied suddenly in full force. As a general rule, these matters are little attended to in the British coke districts, the coal employed being so bituminous as to yield, under either of the conditions above stated, a compact mass, which can endure the effects of carriage, *et cetera*, without sustaining much injury.

The several methods in use for the charring of coal, for whatever purpose, may be comprehended under three heads: namely, distillation in close vessels; heating in open heaps; and a method in which the principle of both is to a certain extent brought into requisition.

Of the first mode it is sufficient to say, in addition to what has been already stated, that the coke so produced is not only limited in amount, but is of such a nature as to render it inefficient where a very compact dense fuel is required, as in the iron furnaces and the like. Indeed, when close distillation is resorted to, the coke is less an object of consideration than the liquid and volatile products; and, therefore, it will be more in keeping with the Editor's plan to speak of it hereafter under the article Gas. By the second method, the advantage is gained of preparing a large quantity of the fuel in a short time; but at the loss of considerable quantities of material, as will be seen afterwards. The third method in which a furnace of a special form is employed, and which admits of operating upon a large quantity of coals at once, is that which is daily becoming recognised as the most economical, for it operates quicker, with less loss, and requires less attention than the others.

Coking by the second method, or the open heap, requires nearly the same operations as the carbonization of wood, only that the mounds are not so large, and they require less attention. Two systems are followed, the one characterized by the round heap or pile process, and the other by the coals being arranged in rows or ridges. For the purpose of coking in heaps, a level plot of ground is selected, the area of the heap marked out, and the coals piled upon it, placing the larger pieces at the base, and so on to the top. Fire is then applied in a cavity of about a foot in diameter, which is formed in the top for this purpose, and the carbonization allowed to proceed. In a short time the entire mass is covered with the fire, owing to the combustible gases which are discharged, and which, igniting, conduct the fire over the whole of the coals, at the same time that they prevent its loss by shielding the heated solid carbonaceous matters from contact with oxygen. When the whole mass is at a red heat, or nearly so, and the dense heavy smoke which is emitted as long as the decomposition of the volatile ingredients in the fuel is actively proceeding has ceased, a light coating of coke ashes, or the rubbish which has accumulated, is thrown on, and the air entirely excluded. Sometimes the mound is covered with straw, dried leaves, or brambles, and coke dust or clay, before it is ignited; but this is not generally thought necessary, as the density of the coal and the downward progress of the fire, till it reaches the base of the heap, are sufficient protection against any greater loss than that which it would sustain even when covered. The period of charring a heap of twelve to sixteen feet in diameter, and two and a half to three in height, extends over two or three days before the work is finished. Wilkinson's modification of the process, by the construction of a chimney in the middle of the meiler, so that it may serve as a draught to any portion of the mass, has been productive of great advantages in coke-making, and has, with slight modifications, been adopted in Staffordshire, on the Clyde, in Scotland, and at several other places. This appendage to the meiler is usually of a conical form, the base being about three feet in diameter, and from one foot and a half to two feet at the top. The bricks are laid so that intermediate channels present themselves all round the pile. At the top it is solid, and closed with a lid. Its height is usually three or four feet. Around the base of this chimney the coals are piled, employing the larger pieces for the base, and putting the smaller ones on towards the top and outer surface. Several channels are fashioned in the mass from the base of the chimney to the outside of the heap, through which a supply of air traverses to the region of combustion. The preliminaries being effected, and the heap coated with powdered coke or rubbish, fire is introduced at the mouth of the chimney, either by means of ignited coals or wood. The caloric which is evolved laterally through the openings in the chimney, very soon ignites the coal adjoining, and the heat extends gradually outwards to the circumference as the charring advances. As soon as the thick heavy smoke from the chimney is replaced by a lambent blue flame, it is significant that the fire has traversed the entire mass. It is now watched till the azure flame abates, at which time the draught of the chimney is cut off, by depressing the cover, and filling any chinks or cracks in the coating with fresh material. After the lapse of a few days, the process is finished, and the coke is ready for drawing. Fig. 57 represents an elevated section of this mode of charring, showing the chimney and the draught holes opening in all its circumference, and thus offering a flue for the volatile products to pass away. Sometimes this kind of meiler is ignited at several parts at the outside, near the channel flues at the base. In a short time the fire will reach almost to the centre. A few air or vent holes may now be made in the covering, by thrusting an iron bar into the heap. The smoke and other volatile compounds issue partly by these, but care must be taken to frequently renew the perforations, as, when the coals are very bituminous, the fusion of the mass is apt to choke them up. In about twelve hours or less after ignition, the fire will have spread over the whole heap, which may then be loosely covered with coke refuse, ashes, *et cetera*, leaving the vent or chimney still free. During two or three days the smouldering proceeds, by which the volatile portions suffer distillation, and are emitted by the orifice last mentioned, and the cooling will have advanced so far as to allow of the coke being used. By this mode of permitting the whole heap to get ignited before covering, and subsequently leaving the chimney open, the elevated temperature is retained sufficiently to carbonize the mass, and at the same time a waste of coke is avoided; moreover, another important advantage is gained in the expulsion of much more sulphur than could be effected if the air were more freely admitted during the operation.

Fig. 57.



It deserves also to be mentioned, that the coke manufacturer, by constructing the meiler upon a moist ground, effects a purification from the sulphur by means of the vapors arising from the soil, and passing through the red-hot mass. In this case the water must suffer decomposition, its oxygen passing over to the sulphur, so as to form sulphurous acid, and the hydrogen constituting, with the carbon, light carbide of hydrogen, thus:—

$$2\,HO + S + C = SO_2 + CH_2$$

When the sulphur is united to a metal, and the aqueous vapor transmitted over it, the following changes are more prevalent, assuming M to represent the metal in combination:—

$$HO + MS = MO + HS.$$

If, however, the heat be too great, or more air than is requisite be permitted to pass through the mass, this decomposition will not take place, and the sulphur in great part remains. The same end might be obtained by suffusing the ground with water before forming the heap.

It should be remembered, however, that in this case, as in the charring of wood, in proportion as watery vapor traverses the incandescent mass, so a loss of the carbonaceous substance is sustained. This will be evident from the above formulæ; but the importance of having the sulphur removed from the coke, especially when destined to be used in the smelting of iron, is much more thought of than the advantage of obtaining a large product.

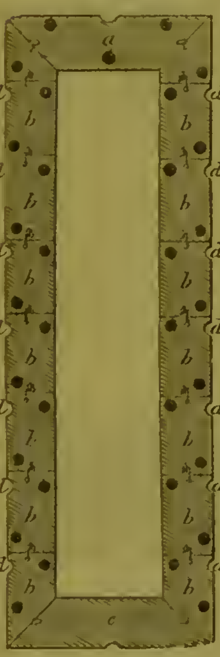
For the most part it happens that the circular mound, notwithstanding the assistance which the central chimney affords, is too massive and solid to allow the heat to operate with its fullest effect upon the coals. The want of this distribution of caloric is supposed to be the cause of the coke retaining more or less hydrogen and oxygen, which injure in some degree its value. To remedy this, the method of *coking in rows* is resorted to. A site is marked out, the extent of which depends upon the amount of coke which is to be prepared. A line is stretched along the length of the plane, in the middle of the space which the ridge is to occupy. At the distance of seven or eight feet apart, stakes, six to eight inches in diameter, are fixed in the ground. Large pieces of coal are then laid at each side of the string, and inclined to one another, so as to leave a channel in the midst. To insure greater strength to the walls, if the first rows may be so termed, the plane of cleavage of the coal should form a right angle with the length of the heap. Other layers of coal in proportion to the size are placed beside and upon the first two, using the largest coal first, till the row is sufficiently high and wide, taking care that air channels are left at intervals in the base. The usual height to which these ridges are raised is about three feet. When completed, the whole is covered with coal dust or cinders, and fire applied at several parts adjoining the air channels; the stakes are likewise drawn, and live coals thrown into the vacant space which they leave. In a short time the whole mass will be in a state of active combustion. As soon as the heat has penetrated to the centre, the pile may be covered more closely, leaving the portion left void by the stakes as free as possible, so as to perform the office of a chimney. In case these should get choked by the fusion of the coal, they must from time to time be cleared by thrusting a bar of iron into them, or into any parts where the combustion is dilatory. As soon as the white flame resulting from the combustion of the carbide of hydrogen disappears, and is succeeded by a lambent bluish blaze, all the orifices are closely covered, and the whole is left to cool.

Such is the simple mode of coking in heaps and rows, but it may be remarked that particular modifications are required according to the kind of coal which is to be carbonized. Thus, when there is a large portion of fusible matter in the coal, care must be taken that the draught holes or flues are sufficiently wide to admit of the increased volume which it acquires by the effects of the heat upon it, without being closed thereby; the fire, also, must be allowed to spread over the whole heap, as well interiorly as exteriorly, before it is partially covered with the refuse matter. When, by a closing of the draught or flue holes, air is prevented from entering to the heart of the mass, considerable time may elapse, and much of the exterior may be consumed, before the interior portions are charred; and it not unfrequently happens that while the outside of a ridge is completely coked, the interior is left intact. As an auxiliary to the process, when very bituminous coals are operated upon, the fire should not be kindled in the chimneys or spaces left by the stakes till the base be well ignited; the facility which these afford for the escape of the products of combustion will expedite the process, and the result will be the general charring of the heap, whereas, if these precautions were not taken, the work would be but partially performed. The same observations will apply when the coal is small, and, therefore, forms a ridge which is less impervious to air. In the latter case, instead of stakes being driven into the centre, brick chimneys are erected, as in the meiler system.

Where there is great demand for coke, and the area admits of the construction of a large heap, one portion may be undergoing carbonization, whilst the other is being constructed, and thus the process of coking may be rendered continuous. The method of charring in ridges is preferred in most establishments where furnaces are not erected, as it affords a better coke, and is more expeditious than the other method. Among the more recognised benefits are the partial purification from sulphur, which arises, as has been stated, from the fact that the steam which evaporates from the base of the heap passes over the coke whilst at a red heat, and operates as already mentioned; hence, to insure this, it is customary, wherever practicable, to cut á dyke around the carbonizing plot, the water from which keeps the ground always damp. Besides the advantages which accrue from the floor of the heap being moist, the water is always required to arrest the too rapid combustion which is apt to take place in some parts of the ridge, and also to extinguish the incandescent charcoal when it cannot be allowed to cool spontaneously.

A modification of this method of coking has been followed for some time at the Janon Works, near Saint Etienne, in France, and is useful for economising the rubbish, slack, or small coal which could not be worked in the manner detailed. It is evident that the adoption of some similar plan at many of the British collieries, where considerable quantities of coal of average quality are allowed to go to waste, would be highly advantageous.

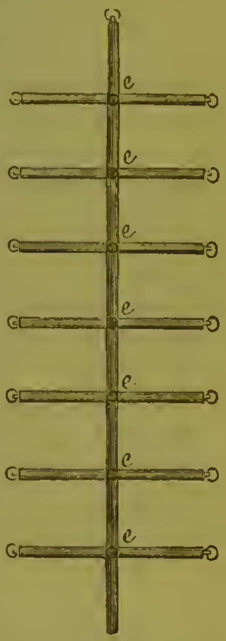
Fig. 58.



The heaps or ridges which are constructed at the establishment alluded to, are almost of the same dimensions as those formed with large coal, and, like the last mentioned, may be either of an oblong or conical form, according as the ground affords the necessary facilities. To construct an oblong ridge, a board, *a*—Fig. 58—is placed in an inclined position, suited to that of the heap, and resting on two iron levers sunk in the ground. Against this are fixed other boards, *b b b*, one over another, and secured by levers or bars of iron sunk in the ground at regular distances apart, and iron hooks. After the sides are ten or twelve feet in length, the prism is provisionally closed by a board, *c*, similar to the first. All these boards are perforated, in order that conical stakes may be introduced to the interior through them, for the purpose of yielding ingress to the air in the spaces which are left after the latter are removed.

The arrangement of the lower conical stakes, by which these internal air spaces are formed, is seen in the annexed Fig. 59, where the stakes are represented in the position they would occupy when passing through the lowermost series of holes, *d d d*, in the walls of the ridge. A large stake, running longitudinally in the middle of the prism, forms the principal one. Upon this other smaller ones are fixed, as at *e e e*, perpendicular to it. These being adjusted, or in readiness, a layer of the small coal, moistened to give it consistency, is thrown in till it rises to the level of the central stake, when the vertical ones are arranged as already stated, and a fresh quantity of coals added. By means of a heavy beater, the mass is rendered as compact as possible. A fresh layer of the slack is added, and beaten down as before, till the mass rises to the level of the second range of holes in the side boards, when horizontal stakes are laid from them, so as to abut against the vertical ones at a slight inclination. After the coal has been arranged in the same manner till it reaches the third level, another series of rollers is laid down as before, only that it is not requisite they should be set obliquely. All these posts are generally three or four inches in diameter, and have a ring in the outer end to facilitate the drawing after the heap is formed. At this period the vertical stakes are drawn out, and then the side ones, beginning with those uppermost, and proceeding to the lowest. When this is done, the boards forming the walls are taken down and laid in continuation of the ridge, and the same order and operations are followed. In this way the prism is extended to any required length, but usually it terminates when it reaches from fifty to sixty feet in length, or even less than this, according to circumstances.

Fig. 59.



Ignition is commenced by lighting some round coal, placed at set distances in the upper holes, as well as in the middle of the heap. Care should be observed that sufficient space is left for the air to traverse these channels. In a short time the fire gains sufficient strength to ignite the whole heap gradually. As this is being attained, attention must be directed to the openings, that they do not become closed through the swelling of the mass, and, likewise, that cracks or fissures forming in the exterior are immediately closed with refuse coal. After the whole mass has become incandescent, and the evolution of whitish flame has ceased, water is poured into the lower longitudinal tunnel. By the conversion of this fluid into steam, and its passage through the mass, a further quantity of hydrogen and oxygen is expelled, as well as some sulphur. When this operation is performed, the fire is extinguished by suffocation in the usual way. From six to ten days are required to complete the operation, and the coals afford half their weight of coke of fair average quality. It is evident that only caking coals are capable of being charred in this manner, as the non-bituminous varieties would not remain compact enough during the period of the firing.

The only drawback to this method, is the considerable consumption of coals which is necessary to ignite the mass, and which amounts to one-twentieth of the whole. By constructing the heap of a conical form, this may be reduced by one-half. It is done by an arrangement of boards, secured as in the prismatic heap, presenting the form of Fig. 60, and including a space of ten or twelve feet in diameter. A square stake, *a*—Fig. 61—is fixed in the centre of the pile, against which lean six conical stakes, *b b b*, placed at equal distances. The latter are perforated in the sides and upper part, for the purpose of receiving other stakes, *c c c*, which assume a vertical and horizontal position to each of the six principal ones. Coal is thrown in, and well rammed down, till it rises about three inches above them, when another series of stakes is laid down similar to the foregoing, only that the smaller stakes leading from the six larger ones are not directed above the preceding, as may be seen from the position of the holes in the larger ones. Another layer of coals is then laid on, and this course is pursued till the pile has risen to a height of three feet and a half, with a diameter of seven at the top. A number of smaller chimneys is constructed by fixing, in the first series of stakes, vertical ones at the points, *m m m*, which rise higher than the top of the pile. In the subsequent details of pulling out the stakes and igniting the heap, no material difference exists between the method already described and that under consideration; the particulars of the carbonization are likewise the same in each. In this way much of the fuel which would otherwise be unsuited to such work as the smelting of metals, or for railways, is made to answer the same purposes as the best coal, and at little expense.

Fig. 60.

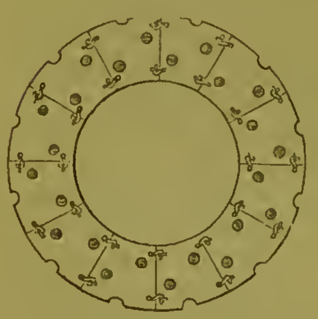
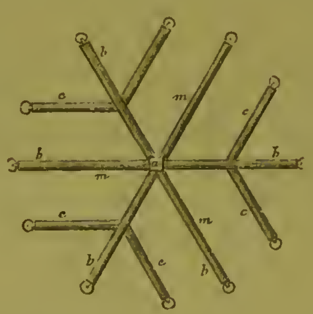


Fig. 61.



Another system to which the coke manufacturer has recourse, is that of heating in ovens. In this case the heat employed for effecting the carbonization is generated within the oven or furnace, and at the expense of a portion of the fuel. Were this not so, the product would be wanting in the necessary density and compactness for the iron furnaces, and, like the coke from the gas-works, would not be adapted for generating high degrees of temperature. The method of coking in ovens is practised also for economy, as not only yielding a larger product of coke, but affording the means of recovering some of the products of the distillation. It is not, indeed, without its inconveniences, more especially if the coals be very much charged with sulphur; for, in this case, the coke retains that injurious element in much larger quantities than if the carbonization were effected in the open meiler. The ovens, however, can hardly be excelled for the production of a hard dense coke; and hence they are employed by several iron-smelters, especially those upon the Tyne.

The commoner arrangement for the coking of coals in this manner, is seen in the annexed engravings—Figs. 62 and 63—the first of which shows an elevation, partly in section, of a series of four ovens constructed in a line, for the purpose of economising the heat; and the other a plan. They have a square or oblong form, with an area of twelve feet by ten, or less, according to circumstances. The height of the furnace is also variable, differing from three to ten feet. Sometimes about twelve hundred cubic feet of coal are charred in each at once. The walls of this construction, including the fireproof facing, are about two feet thick. In the arch is an opening, *a*, two feet in diameter, through which the gases and other products of combustion pass off. No grating is supplied in this case, the air being admitted through a perforated door, *b b b*, about three feet square, in the front near the base. This door is sometimes constructed of a stout perforated cast-iron plate: sometimes it consists of a mere frame, *d*, within which bricks are laid at such distances as will leave sufficient space for the admission of air. It is movable in grooves, *c c*, by means of a chain, *c*, attached to a counterpoised lever. The coals are introduced through this as well as by the superior orifice; but it is stated, that when the charge is supplied from the top, the coke is not so good as when it is deposited in the furnace through the front door. It appears difficult to assign any cause for this, other than that, when the filling takes place from above, the central part becomes so compact as to obstruct the free passage of air through it. Before charging, if the interior be not sufficiently hot, some wood is ignited inside the front door, and

Fig. 62.

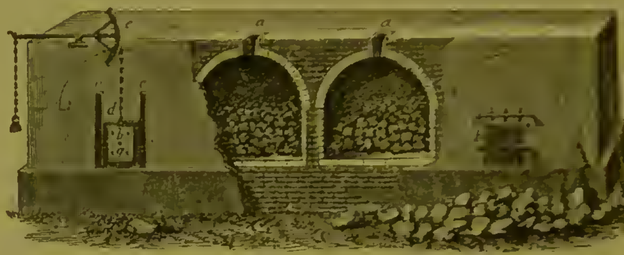
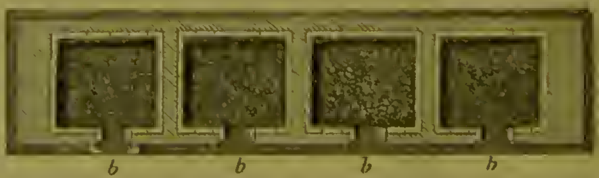


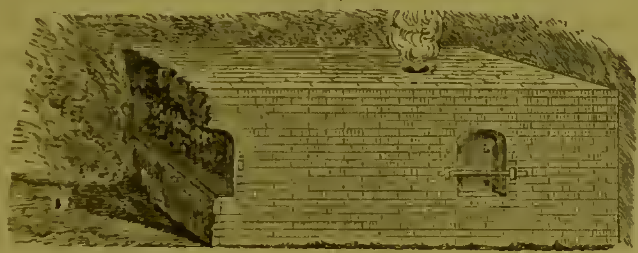
Fig. 63.



allowed to burn, and, at the first charges, the combustion is assisted by throwing powdered sulphur upon the mass. During the evolution of dense volumes of smoke, the top door is left open, and also the apertures in the door at the base; as soon as these disappear, however, both are closed, and the contents are allowed to cool. After twelve hours, or longer according to circumstances, the solid mass of coke is broken, drawn out with rakes, and wheeled off in iron barrows to a receptacle where it is cooled by sprinkling it with water. After a furnace is lighted, the first and second batch of coke which it yields is very much inferior to what is produced when it has been in operation regularly for some time; this arises from the circumstance of the base and appendages not being sufficiently heated. After a few charges have been carbonized, and the masonry has become heated, the coke has not the sponginess which characterizes the first charges; the time occupied is also shorter, and there is no occasion for adding any fire, as the heat of the base and side walls is sufficient to ignite the coal in contact with them.

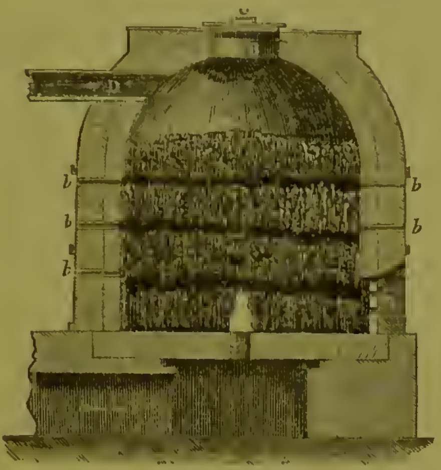
An improved form of this kind of coking oven is used in the neighborhood of Pittsburg in America. This is represented in elevation and section in Fig. 64. For the most part it is constructed of bricks, and on the side of an incline, affording a facility for unloading the coal on the top of the oven, and therefore erected in a position accessible by rail or common road. The hearth is oval, this form being preferred in order to avoid the inconvenience arising from the adhering of the coke to the angular parts; its area is about the same as the English ones, but the depth is only about three feet and a half, instead of being ten, as in the preceding case. In all the other details, the two methods are similar.

Fig. 64.



In many parts of Germany and France, some of the products of the distillation are recovered, more especially the tar. This economy is not so much practised in the *coking* establishments of England, although her maritime wants require considerable quantities of this substance. The kind of furnace or oven constructed for the charring of coal and the collection of coal-tar in Silesia, is represented in section in Fig. 65. The oven is of a cylindrical form, eight to nine feet in height, and four in diameter. Any ordinary building materials are employed in constructing the exterior portion of this oven, but the interior must be composed of very refractory clay or fire-bricks. There are two principal openings, A and B, through which the coal forming the charge is introduced: the aperture, B, is closed by nicely fitting cast-iron lids, C, whilst the former may be secured by bricks and mortar, to which security is given by a cast-iron plate. In the bed and wall of the oven metallic pipes are laid at intervals, and encased with the masonry and brickwork; these serve to conduct air into the furnace for the purpose of carrying on the combustion to such an extent as will be sufficient to char the mass contained in it. They are seen at *a* in the base, and at *b b b* in the wall. All the volatile matters evolved during the carbonization are carried off through the cast-iron pipe, D, to a receiver, wherein the condensible portions are retained. In warm weather, and when work is active, this pipe is immersed in a water tank, intermediate, for the more effectually condensing the tar; but this is not required in the colder seasons. Care must be exercised in filling the oven, to deposit the larger coal upon the hearth, and so on, reserving the smaller for the upper layers. Inside the door, A, a space is left for the introduction of lighted coals or wood; but as soon as the coals have taken fire, the top door as well as the lower one are closed tightly, currents of air being circulated in the interior, through the openings in the wall and base of the oven. The upper rows of holes are closed also, the draught being instituted through the lower series, till such time as the contents of the oven have, at this level, reached a red heat. When this occurs, the orifices in the first row are closed, and those of the next opened, and left so till the fuel seen through them has assumed a red heat, after which they are closed like the foregoing, and the next opened. This process of opening the draught-holes is repeated till the whole of the charge becomes ignited. The time for changing the draught becomes pretty definite when the oven is regularly worked; thus, the coals will appear to glow, when viewed through the lower holes, in ten hours after lighting the fire, and this indicates the fit time for closing them; in about the same period, the second row may be secured in like manner; the third series remains open during sixteen hours, and the fourth only three hours. A period of twelve hours is then allowed for the furnace to cool, at the end of which time the coke is drawn. In this furnace the coals operated upon are slightly bituminous; they afford on an average about seventy-four parts by volume, and fifty-three per cent. by weight, of coke, together with rather more than five gallons of tar. The coke which is thus manufactured is very superior, in every particular, to that which

Fig. 65.

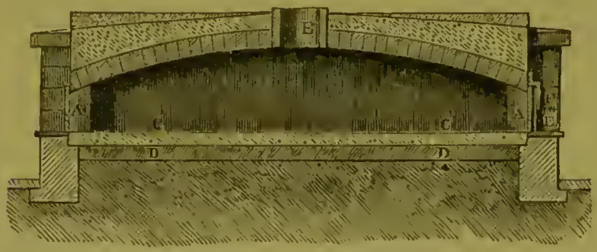


is prepared in the meiler, but the course of operations is, on the other hand, expensive and slow.

In the same locality, a mode is followed for economizing the slack and other small coal, by converting it into coke; and this course of procedure is not very unlike that described for the coking of small coal by the meiler system. The furnace is an oblong rectangle, with doors at each end, through which the small coals are wheeled in, and there, after moistening them with water to make them cohere, they are well beaten down. In the walls a number of air-channels are constructed, leading into the carbonizing space, and pieces of wood are laid between them, extending the whole breadth of the furnace. More coal is piled upon these, and pressed as solidly as possible till it rises as high as the wall, when it is covered with a thick layer of ashes and refuse matter. Some of these ovens are capable of charring from two to three hundred tons of coal, being about eight feet wide, five in height, and from forty to sixty feet in length. Fire is applied to the logs of wood, which have a diameter of four to six inches, and as these are consumed, they develop as much heat as serves to ignite the coal, and the space which they leave acts as a flue by which air is admitted, and the combustion extended to the whole mass. It is said that the loss sustained by the coal subjected to this mode of operation does not exceed twenty per cent.

In the vicinity of St. Etienne, and other localities in France, a coke oven is in use similar to what is represented by Fig. 66 annexed. In appearance it resembles an ordinary baker's oven, with a low arched roof, and a flat hearth without a grate. The bed, C C, of the oven, which is nearly twelve feet wide, and twenty-three feet in length, is composed of a layer of refractory clay, well beaten down, and resting upon a base of cinders or other rubbish, D D, rendered as compact as possible. At each end of this oven there is a working door, A A, two feet nine inches in width and two feet in height, surrounded by a framework of cast-iron fixed in the wall, and in which a small sliding-door, E, moves; there are likewise apertures, F, for affording a view into the interior of the oven; and in the centre of the arch, a space, B, about eighteen inches in diameter, is left to serve for a chimney. The height of the oven, from the hearth to the most elevated portion of the arch, is four feet. Above the arch, which, like the hearth, should be composed of refractory material, common stone, mixed with sand and mortar, serves to give the whole solidity, and to retain the heat. The charge is lighted by first heating the interior with wood, but after a few charges have been drawn, the walls and hearth are sufficiently hot to cause the combustion of the coal. The depth of coal spread upon the hearth should not exceed eight inches if it be of a caking nature; but when it has little of this property, the layer may be ten inches. A little water is sprinkled on the mass to promote its caking, and the whole is rendered as compact as possible. As soon as the layer is uniformly spread, the doors are drawn down nearly to the bottom, leaving a few inches free, however, for the admission of air. At first, aqueous vapor is given off, followed by sulphurous acid and the other products of combustion; but it is found advisable to suppress the rapid evolution of the latter, and to allow the slow expulsion of all moisture, at such a temperature as will be conducive, in the presence of steam, to depurate the coke from sulphur. All these products pass off by the chimney in the roof. When the whole of the moisture has been expelled, the disengagement of the combustible gases becomes more voluminous, and the gases themselves more inflammable; they ignite, and a smoke of a black color succeeds the dense yellow cloud which was given off during the emission of the watery vapors in conjunction with other bodies. When the black smoke appears, the draught is increased by raising the door to the height of three inches, in order to expel the whole of the volatile products. By this means the mass is in a short time raised to a cherry-red heat. After the lapse of from half an hour to an hour, the fuliginous cloud vanishes, and the gases emitted appear whitish. At this stage the heat will have spread over the whole mass, and a contraction in the bulk will have taken place, as may be judged from the appearance of numerous cracks and fissures in the red-hot mass. In about three quarters of an hour, these crevices will have penetrated to the hearth, and the entire contents will be at a full red heat. The doors are now tightly closed, as well as all the other apertures through which air might enter, and the contents of the furnace left to complete the carbonization. It is necessary to watch the operation, lest by the admission of the air through the chimney, which is the only opening left, a loss of coke might occur. After the doors are closed, the flame and smoke still pass off, but the latter by degrees becomes more attenuated and whiter, till it nearly ceases altogether; and as the pressure in the chimney is, at this period, considerably reduced, there is evident danger of a double current being established in it; namely, an outward current of the products of combustion, and an inward one of air. To guard against this, the mouth of the chimney is gradually contracted as the pressure of gases from within becomes less, till at their disappearance it is entirely closed. Attention must now be given to withdraw the coke in such a manner as to retain as much heat in the furnace as possible. To effect this, the doors are thrown open, and the mass of coke quickly broken up with long staves, then raked out, and conveyed away in barrows to a receptacle where it is sprinkled with water whilst red hot, both for the purpose of extinguishing the combustion and removing any excess of sulphur. Another charge is introduced as rapidly as possible, and after the preliminary operations already pointed out have been gone through, the doors are closed, and the charring is again managed in the same manner. Each charge is worked off in about twenty-four hours.

Fig. 66.



Figs. 67 and 68 represent a coking furnace in use in Belgium for carbonizing coal. In these figures, the oven is represented at B B, the chimney in connection with this by A, and a flue leading to the latter by C C. The order of procedure is about the same in this as with the other kinds of ovens described, only that it contains a framework by which the whole of the charge may be drawn out at once when necessary.

Fig. 67

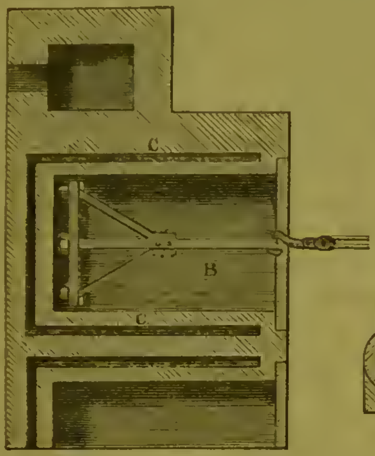
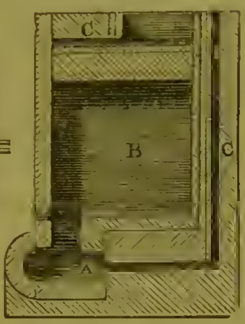
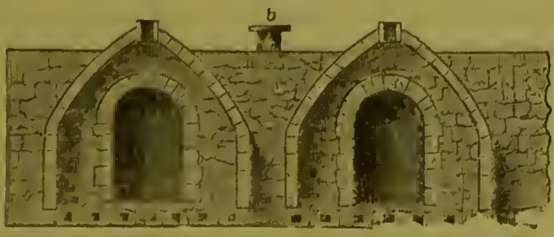


Fig. 68.



In those ovens which work off only a thin stratum of coal, the coke which is formed is never so good as in those in which a thick bed is charred. It is more difficult, however, to carbonize the coal under the latter circumstances, and the product is less in amount. This arises from the fact, that when the mass is thick, and the coals are of a fusible nature, the air is prevented from passing up through the heap, and the result is a superior layer of coke, a middle band of charred material, and the lower layer of undecomposed coal. Even when the coal is not fusible, but contains considerable quantities of ashes, the effects are the same; for, under the influence of heat, the mass cracks into blocks of some dimensions, and the ashes which result from the entire combustion of a portion of the fuel fill the fissures, so that the draught is as effectually cut off as in the preceding instance. The portion of coke which is formed, however, is, in consequence of the prolonged heat necessary for effecting the carbonization, so compact that it claims preference in the iron furnaces to all other kinds, provided no deleterious substances be contained in it. Experience has shown that such a coke resists the pressure of the materials in the furnace, and affords a more intense heat when it comes within the region of the blast, than the looser kinds.

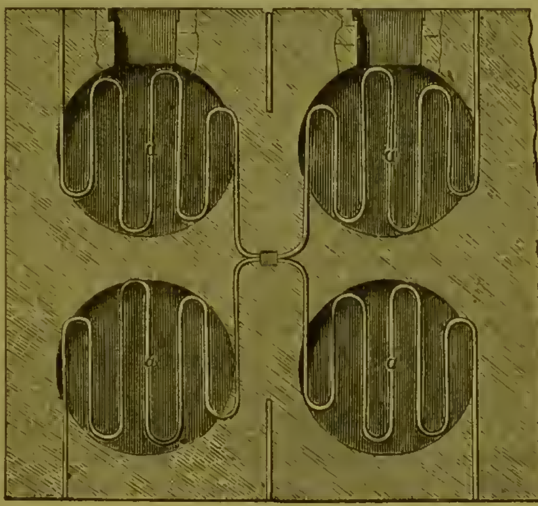
Fig. 69.



To insure the production of such a coke, a modification of the oven has been devised to enable the coke manufacturer to char from seven to ten tons at a time. Fig. 69 represents this form of oven. It is constructed of ordinary refractory materials, and has an area of ten feet square, with a height of about four feet to the springing of the arch or dome of the furnace. To economise the heat, the arch should be so constructed that it will reflect the heat of the fire upon the coal as much as possible, and thereby hasten the carbonization. After the mass of coal has attained a red heat, and the volatile matters are expelled at the chimney, the draught-holes are tightly closed, and the mass is left to itself in this state. Under the action of the confined heat the coke contracts in bulk, and acquires a considerable degree of hardness. When the charge of coke is drawn, the floor of the kiln is cooled down to such a degree as that it will not affect the fresh charge, nor cause a partial distillation of those portions in contact with it, for the coal thus acted upon would yield a lighter and porous coke. This effect is produced by means of a winding or sinuous flue beneath the floor, as seen in *a a*, Fig. 70, which terminates in the chimney, *b*, Fig. 69.

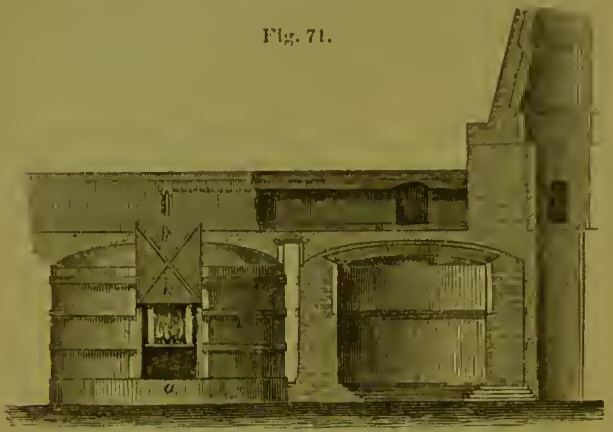
Many other beneficial modifications and improvements are introduced where large quantities of coke are prepared; such as collating several furnaces in a range, by which much loss in the combustion of coal is prevented, owing to the greater amount of heat retained by the materials of the furnace; expedition in charging and discharging the ovens before or after the distillation; and, not the least, the prevention of nuisances by the erection of tall chimneys, which carry the dense volumes of smoke evolved during the action of the fire high into the atmosphere, and, to a great extent, out of the range of vegetal and animal life. Several such improvements may be observed in the coke ovens established at Camden-Town for supplying the railways, especially those of London and Birmingham. Fig. 71 exhibits the disposition of these furnaces, of which there are eighteen or more in a continuous row, and all the volatile products are conducted by a horizontal flue to a tall chimney, which is placed at one end of the line. Like some of those already described, the bed of these furnaces is elliptical in form, the greater diameter being about twelve, and the lesser, eleven feet; the walls are about three feet thick, being

Fig. 70.



lined with refractory firebrick or clay. The soles of these furnaces are constructed of solid materials, well compacted, the upper layer consisting of firebricks. In the front are the openings, *a*, forming the charging doors, which are three and a half feet wide exteriorly, and about two feet three quarters interiorly; they are closed by cast-iron plates, *k k*, five feet and a quarter in height, by four in breadth, to which counterpoise chains passing over pulleys are appended at the upper extremity, and which facilitate the opening and closing of the door.

Fig. 71.



The draught of air passing through the furnaces, is regulated by a damper fixed in the horizontal flue; and to prevent smoke from issuing from the mouth of the chimney, a quantity of air adequate to the carbonaceous gases is introduced into the flue, so that the combustion of those products is effected. Each furnace is charged with three and a half to four tons of coal spread over the base. Fire is applied as well at the base as at the front door in the first charge; but after this is charred, and the walls of the furnaces become heated, ignition is produced by lighting some straw or brushwood under the arch of the furnace. Combustion proceeds regularly till the whole contents are at a red heat, and the entire volatile ingredients expelled. This takes place in about forty hours, at which time the dampers are closed, and the mass of coke is left to cool spontaneously, to render it more compact. After cooling, the coked mass is broken, and then drawn out by an iron rake, the handle of which moves on an iron ring suspended before the opening.

Such are the forms of furnaces adopted, and the processes usually followed in the manufacture of coke, but there are many modifications according to the nature of the coal. Some of these are calculated to afford a larger product, whilst others are intended to manufacture a purer coke than can be done by the ordinary method. The principle involved in those improvements which have in view the increase of the product, is such an equalizing of the temperature as to prevent the heat exercising an undue effect on one portion of coals, whilst another may not be fully charred. The advantage gained, however, even by the most careful management, does not, according to the researches of Karsten, amount, in the case of the charring of coals, to more than five or six per cent. Generally, the quantity of coke which a coal produces depends more upon its atomic constitution, and the amount of ash which it contains, than upon any other condition; and without these data, it is nearly impossible to judge what quantity of coke a coal will yield. The analytical tables, given at pages 80, 81, and 82, will throw some light upon the amount of product from many varieties. British coals usually average from fifty-four and a quarter to about seventy-three per cent. American coals examined by Johnston yield about the same quantities. In either case the inorganic constituents, which take from the heating effect of the coke, are included in the calculated amount. By deducting these matters constituting the ash from the coke, and comparing the principal combustible with the content of the original coal, the numbers will stand in nearly the following centesimal proportion for the varieties mentioned:—

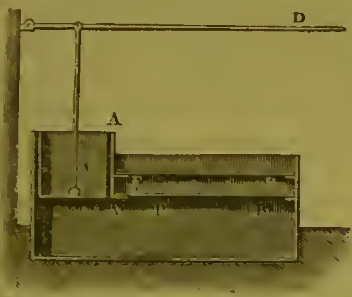
	Entire content of carbon in coal.		Pure coke produced.
Sand coal, ...	75 to 80	....	55 to 65
Sinter coal, ...	80 ,, 85	....	60 .. 70
Caking coal, ...	85 ,, 90	....	60 ,, 80
Anthracite sinter coal, sand coal, ...	90 ,, 95	....	85 .. 94

As already intimated, the quantity of carbon in the coal previous to charring is no certain guide to the estimation of the coke which it will produce; for some varieties, very rich in this element, but associated with hydrogen and oxygen to a considerable extent, yield but a low per centage of fixed matter after the fire has exerted its influence upon the mass. To arrive at the knowledge of how much coke any particular kind of coal will afford, recourse must either be had to an accurate analysis of the substance, or a careful observation of the actual mean produce of a number of charges.

The cost of manufacturing coke by the furnace system, averages in England about one shilling and twopence per ton. In Belgium, the expense amounts to about two shillings and a penny, even when working the large furnaces.

Washing.—Of the improvements for the purpose of producing a better quality of coke, the method of washing lately introduced in France deserves notice. In that country, as well as in Belgium, the veins of coal are intimately blended with shaly matters near the walls, or intersected with such substances, which are in some instances harder, though in others more friable than the coal. In this state, it could not be advantageously employed for coking; and, with a view to economy, it is customary to assort the coal into three classes or qualities. This is done by means of an apparatus called a *gailleterie*, consisting of strong sieves, upon which a stream of water falls. The largest pieces, called *gaillettes*, about two cubic inches in size, are retained in the first sieve; the *gailletins*, or second size, are composed of pieces about one-third of a cubic inch; and the third, or *tails*, consist of fragments smaller than these. From the first, the pieces of schist may be easily removed by picking; but the second, in which considerable quantities of stones and other matters are retained, cannot be so purified; whilst, in the third, or tails, all the earthy, pyritous, and other friable impurities accumulate. M. Marsilly's experiments showed that the coals from the basins of the Mons and of Valenciennes, when so treated, and the products converted into coke, gave a result manifesting considerable difference as to quality. The first selection, or *gailleterie*, afforded a good coke, its ashes averaging from six to seven per cent.; the coke from the next selection was not so good, and retained from seven to eleven per cent. of mineral matters. The original coal, when carbonized without any preparation, yielded a product intermediate between these. It was inferred from such results that the substances which affect the purity of the coal are those which are more friable, and that, by a proper course of treatment, they might be concentrated in the *brees* or final refuse of the coal. To effect this, the coals are subjected in some places to a process of washing, similar to that followed in the purification of minerals. In the pyritous coal localities of the Vosges, this process has been practised for a considerable period; but it was not adopted in other collieries till about 1840, when it was introduced into the coal districts of St. Etienne Rive de Gier, and at the Mons and Valenciennes.

Fig. 72.



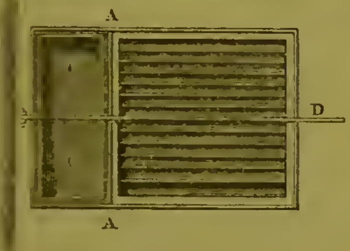


Fig. 73.

Fig. 72, annexed, shows a side elevation of a simple machine used for this purpose; and Fig. 73 a plan of the same. It is a rectangular wooden trough, divided into two unequal compartments by a partition, A A, which does not extend to the bottom. In the larger compartment, a grate, B B, of osiers, iron wire, or perforated zinc, is fixed, and upon this the coals are cast. The trough is filled with water till it rises to the coals on the perforated shelf, when the washing is proceeded with. This is effected by moving the piston-rod attached to a box, C, filling the smaller compartment, up and down in the water by means of an arrangement of levers, D, as seen in the drawings—a movement which has the effect of forcing the water higher in the larger division of the trough, and of floating the lighter portions of the materials, so as to cause the schistose matter to gravitate to the bottom by the motion produced by the alternate rise and fall of the water. When the action has been continued for a sufficient length of time, the superior layer of purified coal is removed from the under layer of impurities. To render this part of the work less troublesome, another perforated bottom, F F, is fixed over the grate, B B. During the washing, the pyritous and other matters fall through the first, F F, and accumulate upon the second one, whilst the purified coal still rests upon the former. Under favorable circumstances, three men can work off from twenty to twenty-five cubic yards of coal in the space of twelve hours by this machine. The water is drawn off from time to time, and supplied by a proper adjustment of stop-cocks, *et cetera*.

The apparatus employed at Commentry for washing the coal, is, on the whole, simpler than the preceding. Figs. 74 and 75 show a plan and elevated section of the apparatus. The pipe, R S, conducts the water by the connecting pipes, T T T, to the stages where the fuel is washed, and which are represented at A B C D, A′ B′ C′ D′, *et cetera*. The coals are deposited in the upper compartment of those beds, as at A B, A′ B′, and when the water passes through, the larger pieces are retained by the gratings which divide these from C, C′; while those pieces which pass through the openings of the first grating are retained in the second, and so on, the water finally passing off by the exit pipe, E F. Several other machines have been tried; but the most economical seems to be that of M. BERARD, introduced about six or eight years ago, and another of a later date, invented by M. TROEHLICH.

Fig 74.

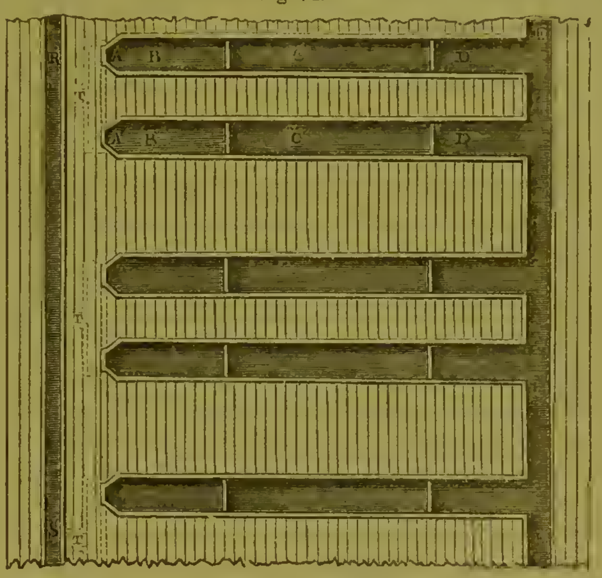
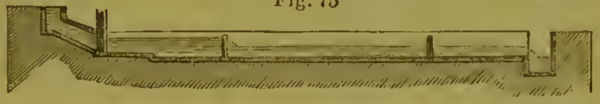


Fig. 75



BERARD'S machine consists of an *elevator*, a *separator*, and what he terms *bancs à lavage*. The elevator is formed of an endless chain of buckets, which lift a certain quantity of the coals from the pit or trough where they are deposited. These buckets empty themselves upon the second part, or the separator. This is a long box divided into compartments by perforated plates, the perforations of which decrease as they extend from the upper to the lower part of the box. By a jigging or shaking motion given to the whole apparatus, the lumps of coal are divided into four sizes, whilst the shaly and pyritous matters settle to the bottom While effecting this assortment of the coal and separation of the sulphur compounds, the same movement forces out the several kinds of coal by a side opening into the third part of the machine, or the *bancs à lavage*. There are likewise long rectangular frames, nine feet two inches in length by four wide, provided with perforated bottoms, the holes in which are so small as to retain the pieces of coal thrown upon them. Like the separator, these boxes are divided into compartments, and are kept quite filled with water. In one part works a piston, by which motion is communicated to the water, so as to cause the material to arrange itself in the order of its density. A current of water made to pass through the box, carries the purified coal beyond the box till it falls into a waggon, in which it is conveyed to its destination; the shaly matter which is left is likewise forced by the current to a trap-door, to which the bottom of the box slightly inclines, and is thus removed. It is said that by one of these machines, the cost of which amounts to about four hundred pounds, and with a daily supply of two thousand gallons of water, not less than one hundred and twenty to one hundred and forty tons are washed per day, at an expense not exceeding one penny per ton.

Troehlich's machine consists of a large circular cistern coopered in the ordinary way, and in this a wooden framework, or agitator, is made to revolve by means of an upright shaft driven by suitable gearing and steam-power. The bottom of the cistern is dished, and in the centre is a hole to which a sort of cast-iron conical pocket is fitted; the lower end of the latter is shut by a valve, opening downwards into a canal with a bottom of wire-gauze. Immediately above the bottom three pipes enter at equal distances from one another, for the purpose of supplying water; and, a little above the level of these, at one side, is a rectangular aperture provided with a valve, which opens upon another canal with a wire-gauze bottom. When in operation, the cistern is kept three-quarters full of water, and into this the coals lifted by chain buckets or otherwise fall through a hopper. The motion of the agitator causes the fragments to describe curves of more or less length, and this allows time for them to arrange themselves in the order of their gravity. Owing to the greater density of the schist and pyritic coals, they fall at once on the inclined bottom, and thence through the grating into the pocket above-mentioned, which is emptied from time to time by means of the valve. The fragments of pure coal pass out by the rectangular opening and fall upon the grating, which has an oscillating motion given to it that serves to impel the fuel to a waggon at the end, while the water filters through the grating. The power of this machine is said to be such, that, with a cistern nine feet ten inches in diameter and depth, and a working force of ten horses, two hundred tons of coal could be washed in a day. The cost of such a machine would be about four hundred pounds.

Four to five per cent. of mineral ingredients are thus removed from the coal; but still the latter retains about two per cent. of foreign matters, which, by a more careful mechanical contrivance, may be removed. The coke from this coal, thoroughly purified, commands in France a higher price, of about two shillings per ton. Even for general consumption, the purified coal is eagerly sought, as well for its superior quality as for its cheapness; because, where the coal is at a distance, the transport of six to ten per cent. of its weight of useless material increases its cost price without adding to its value. For many uses in the arts, it is of great importance to have the coal, when much mineral ingredients are contained in it, subjected to a purifying process. This is the more needed for all such operations as require the use of coke, but in an unequal degree. For railway purposes, the nature of the ash considerably affects the quality of the coke—that is, when it is apt to fuse and run into a slag, as then it impedes the draught, besides injuring the furnace bars. In iron smelting, this property of the ash is not of so much consequence; but the presence of sulphur compounds is deleterious, producing a sulphide of iron which runs into the metal, and impairs its tenacity. Of late years, much pains have been taken with the view of expelling the sulphur from the coke, not by washing, as already pointed out, but by the addition of such ingredients as would, by inducing a double decomposition, liberate this element, or produce compounds with it which are decomposed by the heat. This is the principle upon which the patent of Professor Calvert of Manchester is founded. He directs to add a quantity of salt to the coal in the coking furnace, proportionate to the quantity of sulphur which the latter contains, so as to expel the injurious element, and thereby obtain a coke of a superior quality. The decompositions which concur to produce this effect are:—the reduction of the iron pyrites—bisulphide of iron—into sulphur and a proto-sulphide of the metal by the action of the carbonizing temperature; the former of these is expelled, but the latter would remain in the coal were it not that the vapour of the volatilized salt, coming in contact with it, induces a mutual decomposition; the chlorine displaces the sulphur, the former being assimilated by the alkali metal. The chloride of iron formed is further resolved into chlorine and a subsalt, the former of which reacts upon the sulphide of sodium, producing an alkaline chloride, as well as chloride of sulphur, which is volatilized. It is thus that the coal is said to be purified from sulphur, or, at least, the quantity of this element reduced to a very small amount—even the portion which is left, being in the state of sulphide of sodium, a compound which is less liable to decomposition than the sulphide of iron, and which would be found intact in the slag of the smelting furnace, or in the ash from that of the locomotive. The coke manufactured thus, it is said, evolves no sulphurous acid when taken from the oven; neither is sulphide of hydrogen given off when it is extinguished with water in the usual way; nor is sulphurous acid generated by its combustion in the cupola or furnace. Even ordinary coke may be improved for the wants of the smelter, by adding a certain quantity of chloride of sodium in the cupola. The reaction which takes place in this case is the same as that previously explained.

As already stated, it is evident that coke, like the coal itself, will exhibit considerable difference, both in the nature and per centage of its constituents. A glance at the analytical tables, submitted at page 80, will show the causes of this difference. It will, therefore, be unnecessary to transcribe here analytical results of the composition of coke, further than may be sufficient to indicate the usual qualities supplied to the manufacturer. Of these, nineteen analyses are subjoined:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Carbon,	95·51	85·85	90·53	94·21	93·41	93·05	89·87	84·82	96·42	97·60
Ashes,	2·85	12·07	8·46	5·10	5·80	5·37	8·35	14·40	2·75	1·55
Sulphur,	1·64	2·08	1·01	0·69	0·79	1·58	1·78	0·78	0·83	0·85
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	
Carbon,	94·08	92·44	89·69	91·16	93·54	91·49	94·31	94·67	92·70	
Ashes,	5·04	6·00	8·35	7·65	5·70	7·05	4·97	4·26	5·70	
Sulphur,	0·88	1·56	1·96	1·19	0·76	1·46	0·72	1·07	1·60	
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	

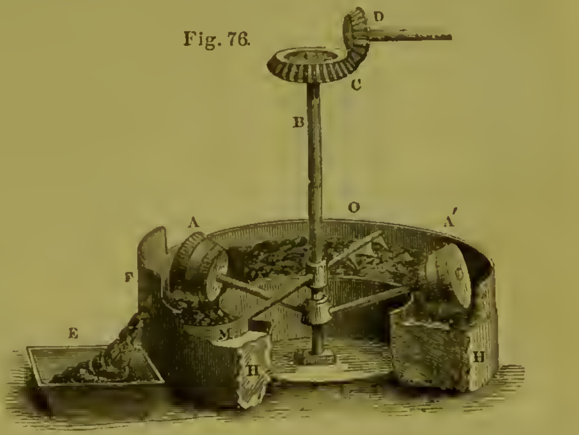
The heating qualities of coke, although easily inferred from the per centage of carbon, will be further considered when the relative value of different kinds of fuel comes to be examined.

Patent Fuel.—In most of the operations of coal-mining, as also in coking establishments, much refuse accumulates which is frequently very rich in combustible matter; but owing to its being in small dust or powder, it cannot be used in the furnace by itself. A similar waste attends the manufacture of wood and peat charcoal, and without the aid of some cohesive matter, this considerable portion of the original fuel becomes useless.

Attention has for a long time been directed to the means of economizing such products in countries where fossil fuel is scarce, and this has not been confined to the *brees* or small refuse matter of the charcoal manufactory, but has been extended to such bodies as sawdust, wood shavings, and other combustibles. In the district adjoining the Caspian Sea, where petroleum springs are abundant, the inhabitants manufacture a fuel, by impregnating clay with the combustible fluid; the clods are afterwards burned in an ordinary hearth. By the gradual evaporation and combustion of the carbides of hydrogen, a fire of considerable intensity results. Indeed, the various contrivances which now come under the notice of the chemist, with a view to the production of artificial fuel, are little more than a copy or counterpart of the method adopted by the Orientals for solidifying the naphtha. The Norwegians have long economized the large quantities of sawdust which they produce, and convert it into a household fuel, by incorporating it with ordinary clay and a little tar, and moulding the whole into bricks. Of late years attempts have been made in this country to introduce a similar practice, by parties who proposed to employ sawdust, brushwood, shavings, spent tanner's bark, and the like substances, in the manufacture of fuel and combustible gases; but hitherto the speculation has not succeeded. The principal ingredients which are taken for the production of artificial fuel are small coal or slack, friable anthracite, the refuse or brees from charcoal and coke ovens, and peat—all of which are mixed with more or less pitch tar, or refuse fatty bodies. The product of some of these ingredients is found in many respects superior to natural fossil fuel, and may be used where the highest temperatures are required. For generating steam, a fuel carefully manufactured with small or refuse coal and pitch, or substances of a similar nature, is often preferred to ordinary steam coal, as it offers conveniences for stowage which coal does not, whilst its heating power is equal to, if not greater than, that of the mineral fossil.

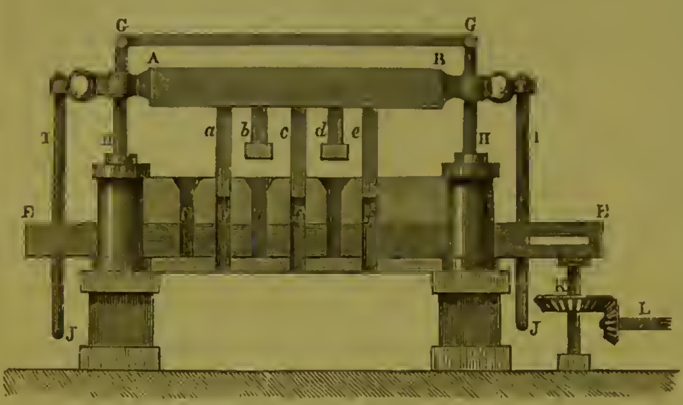
In France, a very fair quality of charcoal is prepared with the refuse from the charcoal furnaces, by mixing it with other substances, such as charred peat, spent tan, and the like, adding tar or pitch. The course of procedure is to grind the solid with the fluid ingredients into a homogeneous pasty mass, which, after being moulded and dried in the air, is subjected to heat in close vessels, and all volatile gases expelled. Fig. 76 represents the mill employed for mixing the charcoal, after being reduced to coarse powder by a preliminary grinding, with the tar or other liquid. It consists of two fluted cast-iron rollers, A A′, connected with an upright central shaft, B, bearing a mitre-wheel, C, which is turned by a pinion, D, gearing into it. The rollers move upon the bed-plate, H H, on which the materials are laid and submitted to the action of the revolving masses till thoroughly mixed. A scraper, O, follows the rollers in the usual way, in order to bring the substances within their range, and by means of another, M, the material is discharged at the slide, F, into the box, E. About six or seven thousand gallons of the mixture are prepared by this machine in twenty-four hours, and the force required to work it is calculated as one horse. From seven to nine gallons of the tar is doled to about two hundredweight of charcoal powder.

Fig. 76.



After the mixture is prepared, the pasty mass is moulded into appropriate forms by a machine such as that sketched in the annexed Fig. 77. By this machine the fuel is formed into quadrangular or circular masses by moulds into which it is introduced, and therein submitted to pressure by means of a heavy log or beam of wood, which carries pistons that work into those frames. In the above figure, the beam is represented by A B moving on the uprights, G H, G H, which keep it in its place by the eccentric motion communicated to the rods, I J, I J; *a*, *b*, *c*, *d*, *e*, indicate the pistons which press the material in, and discharge it from the moulds, *f*, *f*, *f*, *f*, *f*. Two women are constantly employed in filling the moulds; and whilst the one set are being pressed and discharged by the pistons, *a*, *c*, *e*, the others are replenished. When the beam, A B, is raised, the filled moulds are brought under the pistons by a horizontal motion communicated to the casting, E E, by the pinion and wheel, L, K; on the descent of the beam, these are in turn discharged, the others being filled in the meantime, and the motion of E E reversed. In this way the operation of moulding goes on without interruption. An equivalent of six horse-power is required to work this machine, but with it one man and four women can produce about four hundred and fifty bushels of the fuel in a day.

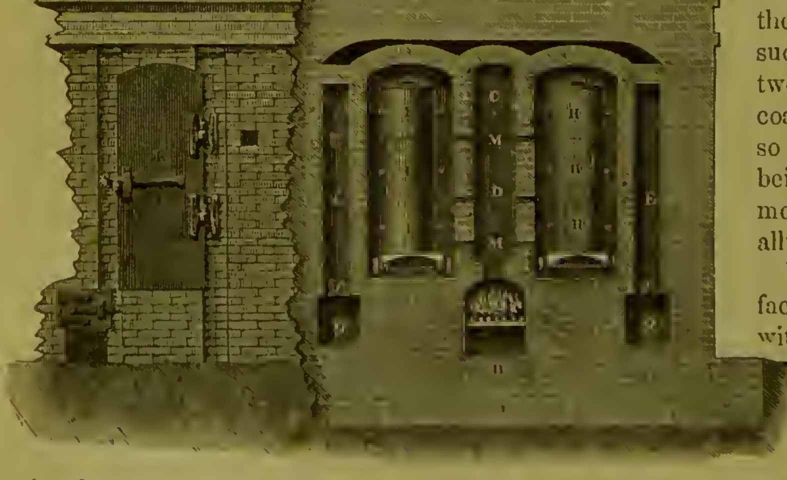
Fig. 77.



After the moulding, the next operation to which the material is subjected is the drying, which is merely an exposure of from two to three days to a current of air.

The carbonization of the bricks is effected in a kind of muffle furnace, shown partly in section, and partly in elevation, in Fig. 78. The muffle in this furnace is about four and a half inches thick of refractory meterial. It is heated by a fire at B, the flame from which circumscribes the whole of the muffle. The products of combustion pass behind the muffles by the channel, C D, but return to the front by the flue, E, and ultimately depart by the openings, *f f*, into the subterranean channels, *g g*, leading to the chimney at the back. The bricks or moulds, which are generally four and a half inches in length, by one and a half in diameter, are packed in the carbonizers, which may be sheet-iron boxes, H H H, or cast-iron cylinders, I I I; these are fixed on trucks, to facilitate their introduction and withdrawal from the muffle by a door in front of the case, lined with firebrick and refractory clay, which may be opened and shut at will. This door is shown at K, and when the carbonization is proceeding, all crevices in it are carefully stopped by clay luting.

Fig. 78.



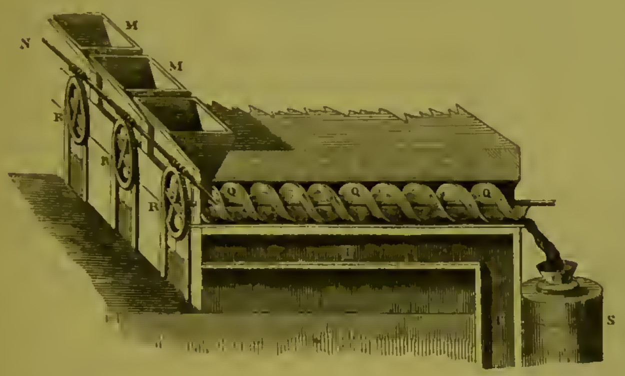
The first effect of the heat is to eliminate moisture from the charring mass; this is followed by some carbides of hydrogen, all of which escape from the cylinders or boxes by small apertures, about the time that the cylinders are beginning to become red-hot. Air is then admitted cautiously at M, M, whereby the evolved gases are burned, giving out as much heat as is sufficient to complete the operation. By having a series of eight muffles and cylinders, two may be charged every six hours, the material being charred in a day. When no more flame is observed in the space, C, examined through M, the workman knows that the charring is completed, and the cylinders are then withdrawn.

Waste cuttings, brushwood, and such materials as could not be employed in the manufacture of ordinary charcoal, may be carbonized, and then turned to profitable account in the manner just described.

The same principle is developed in the manufacture of patent fuel from refuse coal or slack, and also from the waste matter of the coke ovens. In either case, it is necessary to mix them with substances which will give a sufficient consistency to the mass, to cause the particles to adhere whilst coking or burning in the open or furnace grate. In selecting the cementing material, there are some who do not confine themselves to oleaginous, fatty, or tarry matters, but employ also loam, hydrate and sulphate of lime, and various other mineral substances, whilst others—and doubtless this is the best course to adopt—discard the use of all such bodies; and, by a judicious admixture of two varieties of coal, or by operating upon the coal in a particular way, cause it to adhere, and so bring it into such a form as will admit of its being burned as ordinary fuel, or coke. The most important of the patent fuels will here be alluded to.

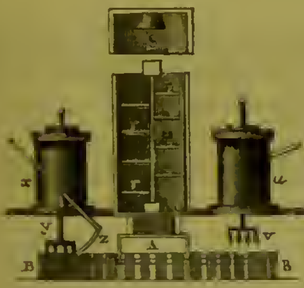
Wylam directs, in his patent for the manufacture of artificial fuel, that small coal be mixed with pitch, and the compound afterwards moulded. The proportions in which these ingredients are taken, are four parts of slack to one of pitch. By means of edge stones, or other machinery, the pitch and coal are ground together, or otherwise mixed, and the mass is put into a large hopper, from which it passes into a retort. This arrangement is seen in Fig. 79, where M M are the receivers or hoppers, from which the mixture is carried into the retort by the plain rollers, R R R, moved by the shaft, N. By the same agency, motion is communicated to an Archimedean screw, Q, which works within the retort, and the matter is discharged at each revolution of the screw as fast as it enters the retort from the hopper. As the retort is maintained at a red heat by the hot air in the flue, T, the material becomes more or less liquefied during the passage from one end to the other.

Fig. 79.



This pasty mass having fallen into the receiver, S, is agitated by the arms, *r r*—Fig. 80—to prevent it hardening into lumps before it is moulded. The moulds, B B, are ranged upon a movable oval table, A, to receive the pasty mass. Into these moulds, rams, connected by pistons, *v y*, are forced, by means of the pressure exerted upon them in the cylinders, *u x*, and which are worked by water. The table is made to revolve by means of a lever, *z*, by the motion which the piston, *y*, communicates to it; and while in its revolution the filled boxes are conducted under the rams of the piston, *v*, those of *y* discharge the formed masses into a receiver, where they are further impressed with the maker's name.

Fig. 80.



If the pitch be not well distilled, and a portion of the oleaginous constituents are retained, the fuel, when stowed where the temperature is somewhat elevated, is apt to ignite spontaneously, in consequence of the evolution and oxidation of those matters. The tendency to this is always greater when fatty matters or oils have been used with the small coal. Numerous instances of the spontaneous combustion of artificial fuels, and even of coals, have been traced to this cause. Such a disaster occurring in the hold of a vessel at sea, is almost certain destruction to the ship.

To guard against this danger, Warlich heats his patent fuel, which is prepared nearly like the foregoing, to a temperature of from 400° to 600° Fahr., in order to dispel all the inflammable ingredients. By this means he produces a species of coke which, even in tropical climates, is quite safe. He mixes a little salt or alum with the combustible ingredients before moulding, that too much smoke may not be evolved during the ignition in the grate. A longitudinal section of the furnace and retort for heating and exhausting the fuel of its more inflammable constituents, is shown in Fig. 81, where A represents the retort, or the chamber wherein the fuel is heated, furnished with sliding-doors and rails, upon which the carriages loaded with the fuel run. Caloric is communicated to the matter in this chamber by means of superheated air forced in by the openings, P P, from the furnace beneath. The gaseous products are conveyed by a pipe, B, and dip-pipe, D, into a main, E, arranged nearly in the same manner as in the manufacture of coal gas. By means of the exhausting apparatus—Fig. 82—the volatile products are drawn off. This consists of two cylinders, H H, open at the bottom, and working in vessels, I I, containing water. The cylinders are connected by a chain with the beam, J, and this again with the connecting-rod, K, by the motion of which the ends of the former are alternately raised and lowered, and consequently the cylinders, H H, also. At each elevation, the gases disengaged flow from the main, E, by the branch pipes, L L, into one or other of these cylinders; and as this cylinder is made to descend, the gases are forced out by the pipes, N N, which dip into the tank, O; they are secured from being driven back into the main by a valve, M M, in connection with the pipes, L L, which opens into the cylinders when the pressure is removed, and shuts when this is exerted.

Fig. 81.

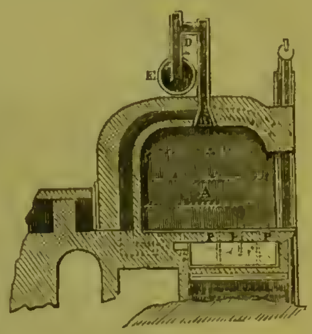
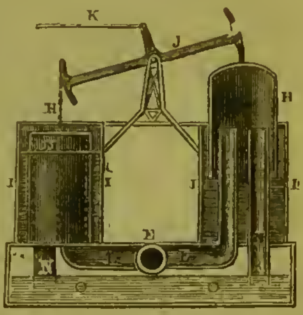


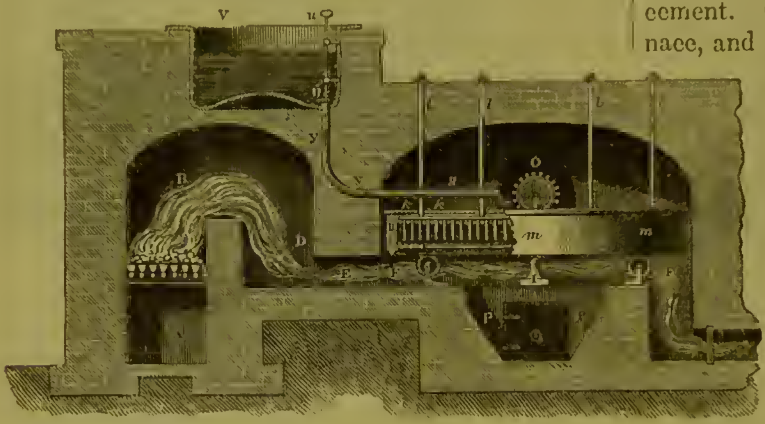
Fig. 82.



At the expiration of six to eight hours the operation is finished, and a fresh charge is introduced.

At Blanzy, the waste coal is worked into a patent fuel in the following manner:—The coal is screened or purified from fragments of pyritous and shaly substances, by placing the matter upon a metal sieve, fixed in a large vat, communicating with a pump by means of a large pipe. When the pump is worked, the water is agitated in the vat, and this agitation causes the matter on the sieve to arrange itself in the order of its density, the heavier particles falling through to the bottom of the vat. The principle of this washing process is precisely the same as that represented in Figs. 72 and 73. After the matter remaining on the sieve is drained, it is removed and crushed between rollers, so as to render it more homogeneous. The coal thus crushed is mixed with seven or eight per cent. of tar, and moulded into bricks. The apparatus by which this is performed is shown in Fig. 83, where B represents the furnace by which the materials are heated, and A the ashpit. D is an arch which serves to depress the flame, so that it shall pass the bridge, E, and spread itself over an extended surface at F F, for the purpose of heating a metal cistern, *m m*, which turns on a pivot, I, and is moved by a pinion, *r*, working into the toothed edges, H H, of the cistern. A flue carries off the smoke to the chimney. The coal, when thrown into the furnace, is spread evenly by a rake, *k k*, attached to rods, *l l*, that pass through the masonry of the furnace, and are secured exteriorly by nuts. A boiler, V, placed over the arch of the furnace holds the tar or pitch in a fluid state, and the necessary proportion may be let into the charge of coal in the furnace by a valve, *u'*, at the bottom, which may be closed at pleasure by means of the rod, *u*. From this valve it flows along the pipe, *y y*, which runs the whole length of the rakes, *k k*. In this way, a comminution of the tar and coal is effected; and when the operation is judged to be complete, two scrapers are lowered, which collect the material, and as soon as the cistern has made about two-thirds of its revolution, two trap-doors are opened, and it falls into a receptacle, P P, below, whence it is afterwards removed while plastic by the door, Q, and pressed into bricks by the hydraulic machine.

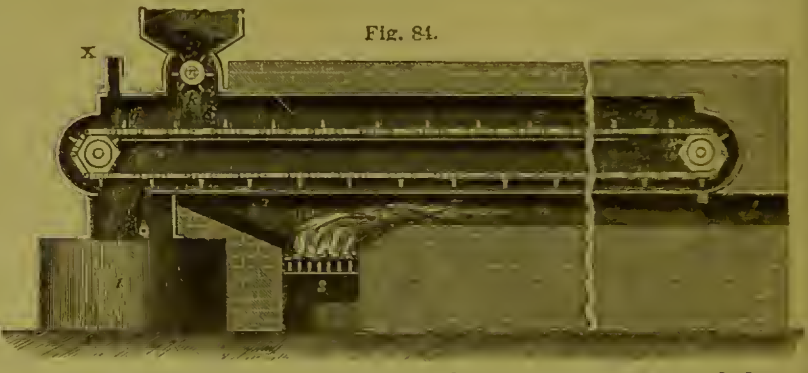
Fig. 83.



Several other patent processes for solidifying small coal and tar into a substance fit to be used as fuel, differ but slightly from the foregoing. The process of Mr. Bessemer is considerably superior to any of these, as it enables proprietors to convert *the whole of the combustible material* into first-class coal, without suffering the loss which is invariably attendant upon colliery operations. It consists in heating small bituminous coal to a temperature at which it fuses, and while in this state moulding it into convenient shapes. By this means, the use of mineral, tarry, or oleaginous cements are dispensed with, and a fuel is produced nearly equal in heating qualities to the round coal of the working, and much more convenient for stowage, from its being in regular shapes. In this operation, a series of very ingenious contrivances are brought into requisition, and made to perform the work with admirable regularity. The apparatus by which these improvements are effected is shown in the annexed engravings—Figs. 84, 85, and 86. Fig. 84 is a longitudinal section of the furnace and retort; Fig. 85 a longitudinal elevation of the pressing machinery, showing also the end of the furnace; and Fig. 86 a plan of the pressing machinery, with part of the furnace and retort.

In Fig. 84, the furnace, *a a*, contains a retort, *b b*, which is represented broken, to indicate that it may be of larger dimensions than here shown. For convenience of erection, it should be made of three lengths united by flanges, and the joints made tight by iron cement. One end of this retort projects from the furnace, and overhangs a part of the pressing apparatus, as shown in Fig. 85. It has a shelf or partition, *c c*, extending nearly to its whole length, and in a tangent line with the upper surface of the polygonal drums, *e* and *d*. Over the latter, two chains are made to pass, which are connected by broad plates of iron, *g*, with flanged ends, which are riveted to the single links of the chain; the edges of the plates, *g*, which project, are beveled so as to form a scraper. Motion is given to this chain by the drums, *e d*, which have projections, *i*, that fall into the spaces between the binding plates, and thus carry them round the drums. On the upper side of the retort there is fixed a hopper, *j*, in the lower part of which, where the slack or coal-dust is placed, is fixed a feeding drum, *k*, with ribs or leaves closely fitting the tube of the hopper. Appended to the side of the hopper are bosses, in which the shaft, *n*, of the feeding drum revolves. The action of this part of the apparatus is as follows:—A fire having been lighted in the fireplace, *s*, the products of combustion pass under the retort, and escape at the open end of the flue, s^1, whence they may be conducted spirally about a boiler, for the purpose of generating the steam required to work the apparatus. When the economy of the waste heat comes to be considered, it will be preferable to set the retort so that the heat may ascend a narrow space between its sides and the walls of the furnace. An enlargement of the fire-chamber is shown at s^2, for the purpose of transmitting radiant heat to the under side of the projecting part of the retort. The temperature of the furnace having brought the retort up to a heat approaching redness, the feeding drum is put in motion, when the small coal or coal-dust will be deposited upon the shelf, *c c*; but the motion of the chains and scrapers will move it along the shelf; and, as each scraper comes in turn under the feeding drum, the coal which has fallen between each of them will be carried forward to the right end of the shelf, off which it falls on to the lower and hotter part of the retort, occupying here

Fig. 84.



as before the space between the scrapers. It will be observed that the entire weight of the chains and scrapers rests on the bottom of the retort, and hence, by the constant passage of the former, the coal is prevented from sticking to it, and rendering its interior surface uneven. This movement not only prevents the caking of the coal to the wall of the retort, but it turns it over repeatedly, thus presenting to the heated surface fresh portions; the effect of the heat is thus equalized, and the fuel is conducted in a softened state over the opening, *f*, in the lower side of the retort, and falls into the receptacle, *t*, where it is submitted, in regular course, to compression in the apparatus, represented in plan in Fig. 86, and in elevation in Fig. 85. In these figures, A is the foundation-plate or framing of the apparatus. It is a sort of shallow box, having a flange around its upper edge, connected to the lower flange by vertical ribs, A′, which divide it externally into panels. Upon the flange are bolted the plummer-blocks, B B, which support the crank-shaft, which is made very strong, to withstand the strains it is subjected to. The crank, D D, has only one throw formed on it, in the centre of which is attached, by a gib-head, between H H, the piston-rod of an oscillating steam cylinder, which, with its induction and eduction pipes, side valve and other necessary appendages, may be constructed in the usual way. This steam cylinder is not shown in the figures, but is placed with its axis in a line vertically over the crank-shaft, and is there supported by trunnions, working as usual in plummer-blocks bolted to the two frames, V V. In order to regulate the motion of the apparatus, fly-wheels, F, are keyed on to each end of the crank. A stout connecting-rod, K, is made with a double gib-head, H H, to receive motion from the same crank-throw. The other end of the connecting-rod, K, is jointed by a gib-head and pin to two lugs, which project from the stout cross-head, I; the ends of the cross-head slide in guides, T T, which are secured by bolts to the flange of the bed-plate. There are three plungers, L L L, keyed into the cross-head, and working in cylinder holes bored truly through the massive block of iron, N, which is secured by bolts to the bed-plate by a flange, and keyed up between steps cast on the same. The upper part of the cylindrical block, N, has a large opening made in it, through the bottom of which the plungers, M, move. Immediately over this opening is the receptacle, into which the softened coal falls from the retort. Another set of plungers, R R R, work in the cylindrical holes of the block, N, at the opposite end to that occupied by M M M. Two guide-bars are bolted to the flange of the bed-plate, and have holes bored in them of sufficient size for the plungers, R R R, to work in. The latter are made large enough to work through both these guides, so that when they are entirely withdrawn from their respective cylinders in the block, N, they will be so guided as to re-enter them without difficulty. The plungers, R R R, are keyed to a cross-head, U U, on the ends of which are fitted, with gib-heads, two long connecting-rods, S S, seen in Fig. 86, the opposite ends of which are likewise furnished with gib-heads, and work on crank-pins, which project from one of the arms of each fly-wheel. These crank-pins are so placed with reference to the central crank-throw, that the latter forms an angle of 45° with them; that is, the one is the one-eighth part of a circle in advance of the other, and thus the action of

Fig. 85.

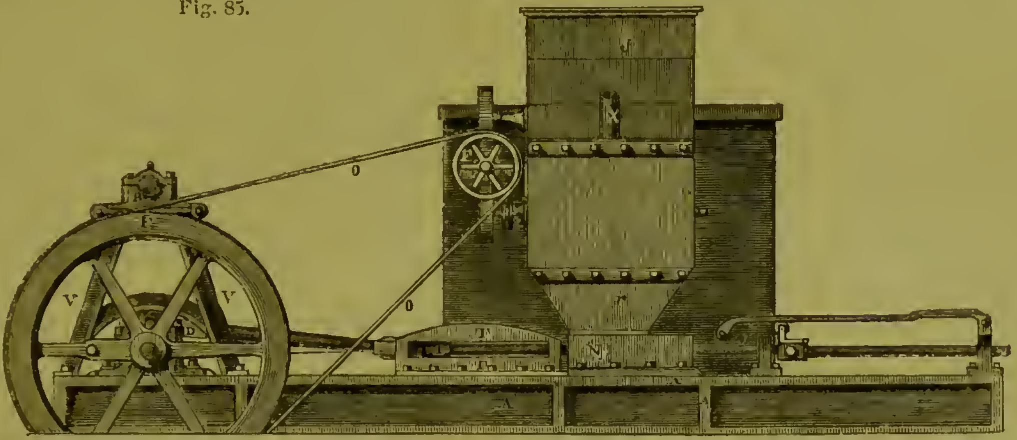
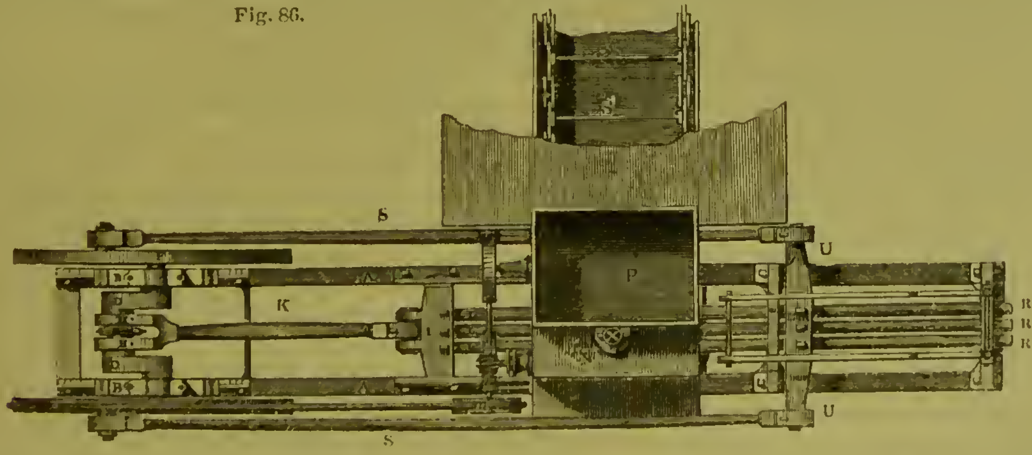


Fig. 86.



their respective plungers will be such, that they will alternately approach and recede from one another at the end of their respective strokes.

The motion of the chain and feeding drum is regulated by passing a strap over one of the fly-wheels; this strap works on the drum, F, on a shaft, *m*, which carries a worm that works upon the upper side of a wheel, keyed on to the shaft of the polygonal drum, *d*, Fig. 84; another worm works into the lower side of a wheel, keyed on to the axis of the feeding drum. From this description, the reader will understand how the steam piston, acting upon its crank, will put in motion the whole apparatus, and that this motion will be regulated by the fly-wheels; also the manner in which the cross-heads will be acted upon by their respective connecting rods, and likewise how the sets of plungers, L L L and R R R, are made to reciprocate in their respective ends of the block, N. Supposing the operation commences when the crank, D, and its connecting-rod are in a horizontal position, and the plungers, L L L, withdrawn as far as possible from the block, N; if one-eighth of the revolution be now made, the plungers, L, will be moved forward a little, and the crank-pins will have risen to the horizontal level, and brought the plungers, R, nearer towards the centre of the block, N. Upon turning the crank an eighth further, L will advance a considerable distance, being at half stroke, and at the same time the plungers, R, will have receded to their starting position. Here it must be observed, that the soft coal which was carried forward by the plungers, L, is compressed between the opposing ends of the two sets of plungers. In this position of L and R, there is a small space between them where any surplus quantity of coal may squeeze out, before it is made to enter the close part of the cylinder; after which they will approach a very little nearer to each other, and thus give the final pressure. If another eighth of a revolution is now made, the relative position of the crank and crank-pins will give a quicker motion to the plungers, R, which will commence receding from the plungers, L, and thus leave no pressure on the solidified lump of coal. If the pressure were not thus relieved, the lump of coal, as it merges from its cylindrical hole in the block, N, would be broken, there being no longer any circumferential support for it. Another eighth of a turn will complete a single stroke of the plungers, L, and have entirely expelled the block of coal, which then falls down into the receptacle, *t*, the plungers, R, having receded still further, and allowed ample space for the block of fuel to fall.

Another eighth of a revolution will commence the return stroke of the plungers, and by following on in the same way until one complete revolution is performed, the respective plungers will again have resumed their original position, and be ready to renew the operation.

If three plungers are made use of, as here represented, three blocks or cylinders of fuel, of equal length and diameter, will be formed at each complete stroke of the engine. As there is a tendency in the block of fuel to stick to the plungers, L, a detaching frame is placed at the end of the machine where the blocks are expelled. This consists of thin bars of iron, fixed on an axis, the ends of which work in lugs on the guide bar, U L; the other ends of the bars are connected by a rod, and upon the cross-head there are bolted two small frames, which carry rollers, upon which the bars rest. When the cross-head, S, moves backward, and allows the blocks of coal to be projected outwards by the plungers, L, then the rollers will pass under the inclined part of the bars, and descend by their own weight, and the rod will come in contact with the blocks of coal, and detach them from the end of the plungers; if they should adhere, the reverse motion of the cross-head will again raise up the bars in readiness for a repetition of the process.

From what has been before stated in reference to the softening process by heat, it will have been understood that the coal-dust may be made to traverse the shelf, *c c*, where it will receive a preparatory heating, and afterwards traverse the bottom of the retort so quickly, as to produce such a slight effect upon the bituminous portion of the coal, as only to soften it a little, and render it fit for the operation of compressing into solid lumps possessing the general properties of the coal from which it is produced. One of the objects for which these operations are performed, is to alter and modify the composition of the resulting fuel, by driving off certain of the volatile constituents of the coal, and thereby rendering such fuel more fitted for certain processes in the arts than ordinary coal. To effect this object, the speed of the feeding and polygonal drums may be adapted so as to subject the coal to any assigned period of operation, and the intensity of the fire being also regulated, the extent to which the distillatory process is carried will be under perfect control. The gaseous matter eliminated from the coal, as it traverses the hottest part of the retort, over the fire-plate, *s*, will have to pass over the surface of the coal which is advancing in that direction, and help to heat it, while it also assists in transmitting caloric to the under side of the shelf, *c c*. Having contributed in this way to heat the materials, it ascends through an opening at the end of the furnace, and passes along over the coal-dust spread upon the shelf, and farther assists in heating it, and finally makes its escape through the pipe, X.

This pipe should have an elbow descending in the manner usually adopted in gas-works, and known as the hydraulic main. In this vessel the liquefiable portion of the volatile matters will be condensed, and the gas may be passed to a gasometer, where it may be stored for use. The fuel resulting from this partial distillatory process will be found to be less fusible in the furnace than ordinary raw coal, and consequently the caking in the furnace will be prevented. To divest the coal of as much of the volatile gases at as low a temperature as possible, an air-pump, constructed in the manner generally employed for exhausting sugar vacuum pans, is used. The pump is connected with the pipe, X, and by the application of steam or other motive power, the retort is kept in a state of exhaustion, which should, if possible, be equal to twenty-four or twenty-five inches of mercury in the barometer.

By this exhaustion, the liberation of the volatile gases from the cells and interstices of the fuel is facilitated, and the residuary matter is rendered much more dense and compact when subsequently pressed. When the air-pump is used, the eduction valve must be made to communicate with the hydraulic main, so that the gaseous matters pumped out may pass off into the gasometer. Instead of applying fire directly to the under side of the retort, as shown in Fig. 84, superheated steam may be used for softening the fuel. When this plan is adopted, a set of cast-iron pipes are arranged in a furnace in the same way as is now commonly used for heating air and steam for blast and other purposes. Into one end of this series of heating pipes, the waste steam of the engine is allowed to pass, and the pipes being kept at a red heat, the steam will acquire a very high temperature, and in this state is to be supplied to the interior of the retort, to soften the coal. The retort, which may be constructed as already described, will not, in the event of steam being used, require any flue beneath it or fireplace, but it ought to be enveloped in brickwork, or some other non-conducting material, in order to retain the heat as much as possible. The steam-pipe should open into the retort at the hopper, *t*, the outlet for the waste vapor and gases being the pipe, X, leading to the hydraulic main and gasometer.

Besides these, several other patents have been obtained for the manufacture of patent fuel from waste combustible materials, many of which are but of little interest.

ANALYSIS OF FUELS.—Having explained, in the preceding pages, the nature of the more commonly occurring fuels, as well as the processes by which certain varieties of them are prepared, to render them better suited for particular uses, it remains only to describe briefly the methods of analysis which are usually followed when determining their constituents, and indicate the way by which their value, in point of heating effect and practical working in the furnace, may be arrived at.

There are various processes whereby the composition of wood, charcoal, *et cetera*, may be found. Many of these are so simple, that any person having only a partial knowledge of chemical manipulation, can conduct them with sufficient accuracy; several, on the contrary, require the experience of the advanced analyst to insure success. The examination, with reference to the quantities of carbonaceous and mineral matters, may be made by simply burning a weighed portion of the fuel in a tared crucible of platinum or porcelain till all blackness disappears, and only the white or brownish ash remains. The difference between the weight of the latter and that of the original substance, will give the proportion of combustible ingredients. But before an estimate of the value of a fuel can be formed, something more than the preceding is necessary; and this will be evident from the consideration of its different applications in the arts and manufactures. For instance, the charcoal or coke manufacturer is chiefly interested in the quantity of carbon which he can retain after modifying the wood, peat, or coal, by the action of heat; he has little regard to the quantity of volatile or liquid products which can be generated from them. The gas-maker, on the contrary, is mainly desirous to secure such materials as will yield the largest volume of gas, whereas the liquid products of the distillation, and the coke, engage only a secondary part of his attention.

To find in the simplest and readiest way whether a fuel, such as coal, is best adapted for one or other of these applications, it is necessary, in the first place, to dry the weighed sample thoroughly, and to find, by again weighing it after desiccation, how much moisture it contained. The heat of a water-bath will serve for this purpose, but an air or oil-bath kept at a temperature of about 300° will answer better. Having determined the quantity of water, the weighed sample must next be subjected to a full red heat in a crucible carefully covered to exclude the air; and, for greater security, the latter is placed in a Hessian crucible, also covered, and containing calcined magnesia. The whole is then introduced into the furnace. The magnesia serves as a support for the crucible containing the substance to be examined, as well as to prevent contact with the outer vessel. The fire is raised to bright redness, and after being maintained at this temperature for an hour, the vessels are withdrawn from the fire, and the enclosed crucible taken out, wiped clean, and weighed. The loss which appears on weighing will represent the liquid and gaseous matters present, and the residue the coke or charcoal which the sample yields. If the per centage of mineral matters be already found, the quantity of carbon in the coke is estimated by deducting this per centage from that of the total amount of coke; but if the proportion of ash has not been ascertained, the crucible containing the coke is heated over a gas-lamp or in the muffle of a furnace, so arranged that a current of air shall circulate through it, till all the charcoal is consumed.

In this way, the quantity of moisture, of volatile matter—consisting of permanent gases and liquids—of coke, and of ash, which a fuel yields, is ascertained; and from them an average inference as to the value of the substance for the production of coke may be deduced, though not for gas-making, because it leaves doubtful how much of the volatile matter consists of inflammable gases, and how much of fluid products. When a very exact knowledge of a fuel is required, nothing short of an elementary analysis can be satisfactory; and this must be coupled with another, showing the quantities of the different products derived from the fuel, when acted upon by heat, out of contact with air. Even both these fail in some cases to give the information required in relation to many applications of the combustible.

By an elementary analysis, is understood the determination of the simple elements of matter entering into the composition of a substance. To enter fully into the particulars of such an analysis would rather confuse than enlighten the reader who may not be conversant with analytical chemistry, and those who are practised in organic analysis do not require a detailed description. A mere outline of the process will, therefore, be given. The first thing to be done is to rasp or abrade a portion of the substance into as fine a powder as possible. A certain weight of this powder is then to be desiccated either in the water-bath or over sulphuric acid in an exhausted receiver, or by passing over it dry air partially heated. The loss in either case will indicate the moisture it had contained. About ten grains of the dried matter are then taken, and intimately mixed with eight or ten times the quantity of chromate of lead or oxide of copper in a heated mortar, and immediately introduced into a dry combustion tube of hard German glass. Care must be taken that the oxidizing agent, whether it be chromate of lead or oxide of copper, be subjected to a red heat immediately before its admixture with the combustible, to insure the absence of water; also, that twenty or thirty grains of dry chlorate of potassa are put into the inner part of the combustion tube, and an inch or two of the oxidizing agent, before the substance to be examined. Having rinsed the mortar with a fresh portion of the chromate or oxide, and added this to that in the tube, the latter is tapped in a horizontal position on the table, in order to form a channel in the upper part for the gases and vapors to flow over. A few fragments of copper turnings are placed in the front part of the tube, and then a little asbestos. Having introduced these, the mouth of the tube is secured by a cork fitted with a small piece of tubing for connecting it with a poised chloride of calcium tube, in which to intercept the water generated during the combustion. To the latter, another tube filled with a solution of caustic potassa, specific gravity 1·26, and commonly known as a LIEBIG's apparatus, also previously balanced, is joined by means of a caoutchouc connector. The success of the experiment will very much depend on the connections of the various parts being quite secure. During the fitting of these parts, the tube may be placed in the combustion furnace. As soon as the several parts are carefully adjusted, a few fragments of ignited charcoal may be laid on the sealed end of the tube containing the chlorate of potassa, and after the air of the apparatus is replaced by oxygen, the combustion is commenced by applying red-hot charcoal to the front of the tube. Care must be taken that the development of gas be not too rapid, as in this case portions may escape absorption; neither, on the other hand, must it be too slow, lest a vacuum be formed in the combustion tube, causing a reflux of the solution of potassa, which would be fatal to the experiment. A steady even stream is kept up by extending the ignited charcoal to fresh parts of the tube as the evolution begins to slacken. After that part of it containing the combustible has been brought to a red heat, and no more gas is evolved, the fire is applied gently to the part containing the chlorate of potassa, so as to produce a gradual stream of oxygen gas, the combustion tube being still kept at a red heat. This has the effect of forcing over into the absorbing apparatus any carbonic acid and aqueous vapor which may remain, and at the same time insure the entire combustion of any particles of charcoal that may not have been exposed to the full heat. Finally, the closed point of the tube is broken, and a U-shaped tube containing fragments of pumice-stone, saturated with sulphuric acid in one limb, and pieces of hydrate of potassa in the other, is connected with it; suction is then applied at the open limb of the potassa apparatus, to draw over all carbonic acid and moisture; after which the chloride of calcium tube and bulbs are detached and reweighed, and the increase in each case noted carefully, as from this the carbon and hydrogen of the substance is calculated.

The calculation is founded upon the data afforded by the composition of water and carbonic acid—namely, that nine parts of the former contain exactly one of hydrogen, and twenty-two parts of the latter six parts of carbon. All the water resulting from the combustion of the hydrogen with the chromate of lead, *et cetera*, is retained in the chloride of calcium tube, and the whole of the carbonic acid, generated under similar circumstances, is absorbed in the bulbs; hence, when due care has been exercised, the results are very accurate. Sometimes a second chloride of calcium tube is attached to the apparatus for absorbing the carbonic acid, when the amount of nitrogen in the sample is appreciable, with the view of arresting the aqueous vapor which this non-condensable gas carries with it from the potassa liquor. It will be evident, indeed, that, in almost all cases, this precaution ought to be adopted; for even when no nitrogen is contained in a substance submitted to organic analysis, the air drawn over at the termination of the combustion becomes loaded with moisture in passing through the bulbs, and so far the weight of the latter is reduced, on which account the amount of carbon found is less than the true quantity; but by attaching a second chloride of calcium tube, filled with fragments of this salt after being fused, and which should be weighed before and after the operation, and adding the gain to that of the bulbs, this error may be prevented.

Instead of compounding the substance with a solid oxidizing agent as in the manner described, it may be introduced at once, provided it has been previously dried, into the combustion tube in a tolerably coarse state, and a stream of pure dry oxygen gas passed over it. The tube should be open at both ends, one of which is to be put in connection with the reservoir of oxygen, and the other attached to the usual absorbing media. It is necessary that the oxygen be entirely free from carbonic acid and moisture, and for the greater safety it should be transmitted through a U-tube, holding in one limb fragments of fused chloride of calcium, and in the other pieces of solid potassa, before entering the combustion tube. In this process it is absolutely essential that the potassa apparatus should have a chloride of calcium tube connected with its escaping limb, otherwise the excess of oxygen would carry with it considerable quantities of aqueous vapor, and so reduce the indication from which the carbon is to be calculated. Connection of the several parts being made, a gentle stream from the reservoir is allowed to flow through till all the air is displaced. As soon as this happens, heat is applied to the tube by placing incandescent charcoal around it in the usual progressive way, the current of oxygen being still maintained, till it assumes a red heat, or nearly so, and it is kept in this state till all the carbonaceous matter of the substance operated upon is consumed. Gas may be very advantageously substituted for charcoal in conducting an operation of this kind. When all combustible matter is eradicated from the tube, the fire is slackened, and the current of oxygen maintained for a short time. The parts for absorbing the water and carbonic acid eliminated during the foregoing process are detached, wiped, and balanced, as already detailed, and the hydrogen and oxygen are calculated from their augmentation in weight.

To estimate the nitrogen, a second combustion is in some cases requisite. When the quantity is ascertained volumetrically, the work may be accomplished at one combustion, by establishing a connection between those parts in which the hydrogen and carbon are retained as water and carbonic acid, and an apparatus for measuring the gas. A long combustion tube is required in this instance, so as to admit of a few inches of it being filled with copper turnings, to decompose any binoxide of nitrogen which may be produced during the action of the heat. The nitrogen traverses the chloride of calcium tubes as well as the potassa bulbs, and finally enters the graduated tube, and displaces the mercury with which it is filled. When the operation is finished, some oxygen is generated from the chromate of potassa, in order to force over all the nitrogen and other gases remaining in the apparatus. A portion of this oxygen enters the graduated jar or tube, and must be removed before reading off the volume of nitrogen. For this purpose, after reading off the volume of mixed gases, a quantity of hydrogen equal in bulk to this mixture should be added, and as soon as diffused a measured portion should be transferred into an eudiometer, and exploded by the electric spark. By noting the reduction in the portion taken, the quantity or volume of oxygen in the whole may be ascertained, from the knowledge that one-third of the decrease is oxygen. Deducting the volume of oxygen thus found from that of the mixed bulk of oxygen and nitrogen, the remainder will be the volume of the latter in the portion of the substance submitted to combustion, and from which the weight is deduced, since, at a barometric pressure of thirty inches and a temperature of 60°, the weight of one hundred cubic inches of nitrogen is 29·2914 grains.

Will and Varrentrap's method is a considerable improvement upon the system of analysis pursued in the determination of nitrogen, inasmuch as it dispenses with the use of mercurial troughs, graduated measures, barometers, thermometers, *et cetera;* it is besides much simpler and less laborious, for whilst numerous corrections have to be made for temperature, pressure, and the like in the old process, by this the work is most accurately performed by simply weighing. It is based upon the property which the fixed alkalies have, of converting nitrogen, in whatever state it is contained in a substance, into ammonia, when aided by heat. The ammonia is fixed by an acid—generally hydrochloric—and subsequently in the form of ammonio-chloride of platinum, which is collected, dried, and weighed, and the nitrogen calculated therefrom; 222·5 parts of the salt representing fourteen parts of the gas.

The agent used for the conversion of the nitrogen into ammonia is soda-lime, which is prepared by slaking caustic lime with a concentrated solution of hydrate of soda. The compound should be thoroughly dried, and kept in well-stoppered bottles. In the cold it does not act upon the nitrogenous element of the substance to be analysed, and, therefore, both bodies may be mixed in a mortar, provided they are thoroughly dry, without any fear of ammonia being disengaged or loss occasioned. The ordinary combustion tube answers the purpose, and the course to be pursued is the same as that already mentioned for mixing the ingredients and heating, *et cetera.* The details of the estimation of the ammonia, quantitatively, have been already stated at page 198, Vol. I., to which the reader is referred.

The modification of this process, introduced by Ullgren, may be advantageously noticed here. The combustion with the soda-lime is essentially the same in this as in the preceding operation; the only difference lies in the manner of condensing the ammonia adopted by this chemist. Fig. 87 represents the form of apparatus employed. In this cut, A and B are two U-shaped tubes, in the first of which the connector from the combustion tube opens; the upper portion of the first limb of the part A is charged with a plug of asbestos, *a*, and in the remainder, *b*, small pieces of hydrate of potassa are placed; fragments of glass occupy the bend, *c*, and the second limb, *d*, is filled with little lumps of caoutchouc. A tube, *e*, bent at right angles, and passing through perforated air-tight corks, connects A with B, which is filled with dry sulphate of zinc, and which should be accurately weighed before the experiment. The asbestos in the portion *a* prevents solid particles from passing by the force of the vapor upon the potassa; the latter absorbs the carbonic acid and water, leaving the ammoniacal vapor and hydrocarbon gases to traverse further; the pieces of caoutchouc take up the combustible products, so that only the ammonia enters the tube B, where it is completely absorbed by the zinc salt. To insure accuracy in this operation, it is directed that the part A be immersed in water marking 170° before and after the experiment, so that any ammoniacal vapors contained in it may be driven over to B.

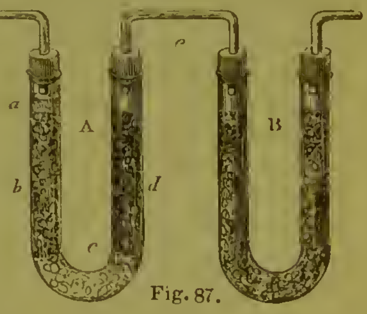


Fig. 87.

By weighing the tube B after the whole of the volatile alkali has been taken up, the increase of weight will show the quantity of ammonia produced, and from this the nitrogen is found, for seventeen parts by weight of the dry ammoniacal gas represent fourteen of nitrogen.

Having, by one or other of these processes, arrived at the knowledge of the quantity of carbon, hydrogen, and nitrogen contained in the fuel, the oxygen, if any, will be the difference between the combined weight of the three, and that of the entire organic or combustible matter. Sometimes, however, it is necessary to consider the sulphur in the analysis of coals, when this element is present in appreciable quantity; because, during the combustion of the substance in the air, it becomes oxidized, and passes off with the carbonic acid and water as sulphurous acid. Its quantity may be determined by deflagrating a known weight of the coal with about two parts of nitre, and eight or ten of chloride of sodium, care being taken that both compounds be free from sulphuric acid; the sulphur is by this means oxidized into sulphuric acid, which becomes fixed by combining with the base of the nitre. By washing the mass with water, precipitating the acidified solution by chloride of barium, collecting the sulphate of baryta, and drying, burning, and weighing the latter, the quantity of sulphur may be calculated. About five-eighths of the portion of sulphur should be deducted from the oxygen or loss expressed in the foregoing, and the difference taken as the true value of the oxygen contained in the compound.

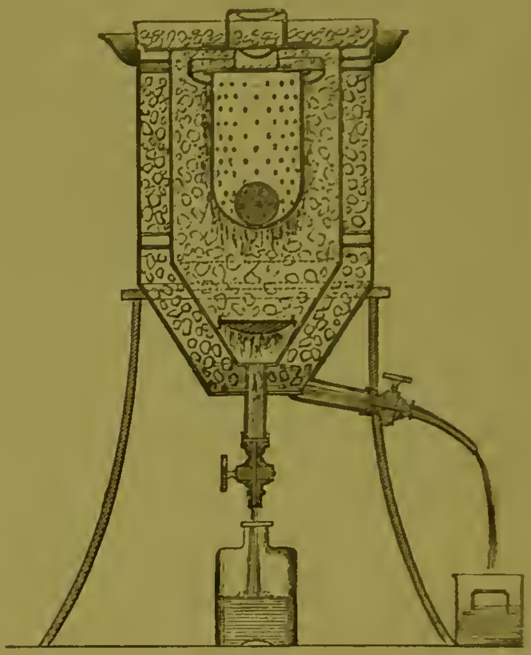
Although the ultimate analysis gives a comprehensive insight into the nature of a fuel, and likewise a means of finding its heating power theoretically; still it leaves much to be desired in practice to enable one to form a correct estimate of its actual heating effect in manufacturing operations. Many circumstances concur to render the amount of work which a given quantity of fuel will perform, less than theory indicates—the principal cause of the discrepancy being the want of such an arrangement of furnaces, as that the whole of the caloric should be directed to, and actually enter into, the performance of the work to be done. This is a desideratum which can scarcely be expected to be attained in so complete a manner as to yield practical results, agreeing exactly with calculations founded on the nature of the fuel; the closer, however, that one can approach to this standard the greater will be the economy realized, and the nearer will the practical results coincide with the deductions of theory.

To arrive at an exact knowledge of the actual quantity of heat which a fuel ought to produce by combustion is impossible, no means being at hand for insuring definiteness to the result; but when, as in the determination of the atomic equivalent of a body, an arbitrary standard is taken, and the quantity of heat which other bodies produce is estimated with relation to such a standard, a comparative measurement is arrived at, which, though not expressing the absolute amount of heat produced, serves all the requirements of the arts. The arbitrary standard assumed, is the quantity of the fuel required to raise the temperature of a given weight of water a certain number of degrees, or the quantity of water which a given weight of the fuel or combustible will raise one degree. This amount, whatever it may be, is taken as the unit of heating power, and the number of such units, or the fractions thereof, which an equal weight of any particular fuel indicates by experiment, is taken as the heating or calorific power of that combustible.

Estimation of Heating Power.—Several investigators have bestowed considerable attention upon the subject of the quantity of caloric developed by the combustion of different substances. Lavoisier, Laplace, and Rumford, were the first to enter this field, and the research has been prosecuted with increasing success by several others, down to the recent investigations of Despretz, Dulong, and Andrews. The principle upon which one and all founded their experiments, was that of determining the effect produced upon a third body by the heat given out during the union of the combustible under examination with oxygen.

In the experiments of Lavoisier and Laplace, the body employed for this purpose was pounded ice, which was so applied around a balloon as to intercept all the heat. Fig. 88 shows a section of their apparatus, which they termed a *calorimeter*. The heating power was estimated in this case from the quantity of water produced by the melting of the ice, and which flowed into the receivers, as seen in the engraving. These philosophers determined the amount of heat requisite to melt one pound of ice, as being sufficient to raise the same weight of water at 32° to 135°, or 103 pounds of water one degree. The more accurate experiments of Prevostaye, Desains, Regnault, and others, as stated in a preceding part of this article—Vol. II., page 20—have shown that the heat which melts one pound of ice is sufficient to raise an equal weight of water to 142°, or seven degrees higher than was estimated by Laplace and Lavoisier.

Fig. 88.



A moment's consideration of this method will convince the reader that it was liable to lead to wrong results, because it was impossible to recover the whole of the water produced by the liquefaction of the ice. This is the principal reason why the numbers given by these original investigators are too low. Rumford substituted water for the ice, the increase of the temperature of which, after the absorption of the caloric, as indicated by a delicate thermometer, was taken as the measure of the heating power of the substance tested. Many improvements have been made on Rumford's method, which is now generally followed in the prosecution of these inquiries. The heating value of any substance is estimated from the number of pounds or parts of a pound of water, which one pound weight of the substance to be tried will raise one degree of Fahrenheit. The following table shows the results arrived at by different experimenters:—

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or units of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible.	Authorities.
Hydrogen,	H	HO	20,624	2,578	Despretz.
			23,640	2,955	Despretz.
			21,375	2,672	Lavoisier.
			24,000	3,000	Dalton.
			34,743	4,343	Dulong.
			34,792	4,349	Hess.
			36,000	4,500	Crawford.
			34,666	4,333	Grassi.
			34,662	4,333	Favre and Selbermann.
			33,808	4,226	Andrews.
Carbon,	C	CO_2	3,000	1,125	Dalton.
			5,175	1,941	Crawford.
			5,325	1,997	Rumford.
			7,167	2,688	Dulong.
			7,237	2,714	Lavoisier.
			7,815	2,931	Despretz.
			7,912	2,967	Despretz.
			7,714	2,893	Grassi.
			7,900	2,962	Andrews.
Carbonic oxide,	CO	CO_2	1,875	3,031	Dalton.
			2,634	4,609	Dulong.
			1,854	3,244	Grassi.
			2,431	4,254	Andrews.
Phosphorus,	P	PO_5	4,500	3,532	Dalton.
			7,500	5,696	Lavoisier.
			5,747	4,509	Andrews.
Sulphur,	S	SO_2	1,500	1,500	Dalton.
			2,571	2,571	Hess.
			2,601	2,601	Dulong.
			2,307	2,307	Andrews.
Antimony,	Sb	$Sb\,O_3$	961	5,875	Dulong.
Zinc,	Zn	$Zn\,O$	1,314	5,290	Dulong.
			1,301	5,366	Andrews.
Tin,	Sn	$Sn\,O_2$	1,233	4,545	Dulong.
			1,144	4,230	Andrews.
Protoxide of tin,	$Sn\,O$	$Sn\,O_2$	534	4,473	Dulong.
			521	4,349	Andrews.
Iron,	Fe	$Fe_3\,O_4$	1,702	4,340	Dulong.
			2,088	5,325	Despretz.
			1,576	4,134	Andrews.
Cobalt,	Co	$Co\,O$	1,080	3,995	Dulong.
Nickel,	Ni	$Ni\,O$	1,006	3,723	Dulong.
Copper,	Cu	$Cu\,O$	632	2,512	Dulong.
			602	2,394	Andrews.
Suboxide of copper,	$Cu_2\,O$	$2\,Cu\,O$	244	2,185	Dulong.
			256	2,288	Andrews.
Cyanogen,	$C_2\,N$	$2\,CO_2,\,N$	5,195	4,241	Dulong.
Marsh gas,	$C\,H_2$	$CO_2,\,2\,HO$	6,375	1,594	Dalton.
			13,185	3,296	Dulong.
			11,098	2,774	Grassi.
			13,158	3,289	Favre and Selbermann.
			13,108	3,277	Andrews.
Olefiant gas,	CH	$CO_2,\,HO$	6,600	1,925	Dalton.
			12,030	3,296	Dulong.
			8,436	2,461	Grassi.
			11,900	3,471	Favre and Selbermann.
			11,942	3,483	Andrews.
Alcohol,	$C_4\,H_6\,O_2$	$4\,CO_2,\;6\,HO$	4,350	2,084	Dalton.
			6,750	3,234	Rumford.
			6,909	3,311	Dulong.
			6,566	3,146	Grassi.
			7,183	3,442	Favro and Selbermann.
			6,850	3,282	Andrews.
Ether,	$C_4\,H_5\,O$	$4\,CO_2,\;5\,HO$	4,650	1,792	Dalton.
			8,025	2,093	Rumford.
			9,431	3,634	Dulong.
			9,027	3,480	Favro and Selbermann.
Wood spirit,	$C_2\,H_4\,O_2$	$2\,CO_2,\;4\,HO$	5,839	3,893	Grassi.
			5,304	3,536	Favre and Selbermann.
Fousel oil,	$C_{10}\,H_{12}\,O_2$	$10\,CO_2.\;12\,HO$	8,959	3,285	Favre and Selbermann.
Amylic ether,	$C_{10}\,H_{11}\,O$	$10\,CO_2,\;11\,HO$	10,188	3,353	Favre and Selbermann.
Acetone,	$C_3\,H_3\,O$	$3\,CO_2.\;3\,HO$	7,320	3,317	Favre and Selbermann.
Rock oil,	$C\;H$	$CO_2,\;HO$	7,335	2,139	Rumford.
Oil of turpentine,	$C_5\,H_4$	$5\,CO_2,\;4\,HO$	4,500	1,339	Dalton.
			10,496	3,187	Grassi.
			10,874	3,301	Favre and Selbermann.
Oil of lemons,	$C_{10}\,H_8$	$10\,CO_2,\;8\,HO$	10,663	3,237	Favre and Selbermann.
Terebene,	$C_{10}\,H_8$	$10\,CO_2,\;8\,HO$	10,959	3,327	Favre and Selbermann.
Camphor,	$C_{10}\,H_8\,O$	$10\,CO_2,\;8\,HO$	5,250	1,847	Dalton.

Name of Combustible.	Symbol.	Symbol of product of combustion.	Pounds of water raised 1° by one pound of substance or units of heat.	Pounds of water raised 1° when one pound of oxygen combines with the combustible	Authorities.
Olive oil,	$C_{10}H_8O$	$10\,CO_2,\ 8\,HO$	6,675	—	Crawford.
			7,800	—	Dalton.
			9,045	—	Rumford.
			9,862	—	Dulong.
			11,100	—	Lavoisier.
			9,300	—	Rumford.
			7,800	—	Dalton.
			8,370	—	Rumford.
			7,273	—	Crawford.
			7,800	—	Dalton.
			9,472	—	Rumford.
			9,975	—	Lavoisier.
			2,105	—	Dalton.

The fifth column in the preceding table has been given, as having reference to a law propounded by Welter, namely, that all combustible bodies disengage the same amount of heat during their combination with the same weight of oxygen; or, in other words, that the caloric developed was proportionate to the amount of oxygen assimilated during the combustion. Welter founded this theory upon the results of Laplace, Lavoisier, Despretz, Rumford, and others, which must be admitted to be less trustworthy than those obtained by Dulong, Grassi, Andrews, and other modern investigators; and it will be seen that when the numbers of the latter are adopted, the relation sought to be established does not hold good. To give one instance: hydrogen combines exactly with three times the quantity of oxygen that carbon takes up, and so from Welter's theory the heat developed should be three times greater when hydrogen is burned, than when an equal weight of pure carbon is subjected to the same process; but from the results of the last-mentioned chemists, the ratio is between one to four and one to five. This wide difference is only observable, however, with combustibles very dissimilar in their nature, for when they approach to identity in physical appearance, as wood, peat, and coal, the estimation of the oxygen taken up gives an average indication of the heating power of the substance, which, without being absolutely correct, will answer most purposes.

Berthier has founded a system of analysis upon this theory, by which the oxygen is estimated, and therefrom the heating power of the fuel deduced. It is easy and expeditious, and may, under the foregoing circumstances, be occasionally adopted. He mixes a weighed portion of the finely-powdered fuel with thirty to forty times its weight of oxide of lead—litharge—and introduces the compound into a fireclay crucible, pressing it gently, and covering the whole with a thick layer of the litharge. The crucible is then carefully closed, and placed on the fire, where it is gently heated till the whole of the carbon and hydrogen is burned. During this process, the mass, being semifluid, is considerably distended by the carbonic acid and water, resulting from the combination of the elements of the fuel with the oxygen of the metallic oxide; towards the end of the operation, therefore, the fire should be quickened, and as soon as the crucible has attained a bright redness, it should be taken out, and its bottom struck gently against a stone or piece of iron, so as to cause the particles of reduced metal to accumulate and form a button. As soon as cold the crucible is broken, and the metal, coated with oxide of lead and slags from the ashes of the fuel, is abstracted. It is cleaned from the adhering impurities by a few blows of a hammer upon the anvil, and subsequent brushing, after which it is weighed. From the number thus found, the oxygen required for the combustion of the fuel is calculated, since it is derived from the oxide of lead—a definite compound of equivalent proportions of lead and oxygen. When pure carbon is operated upon in this way, it has been found that about thirty-four and a half times the weight of the sample of metallic lead has been obtained. This amount of metal stands in a definite relation to the oxygen entering into the combustion, and, consequently, according to the law propounded, to the heating power of the fuel also; for, supposing a certain weight of metal to be produced, the following ratio will give the heating power of the fuel: namely, as the metal obtained when operating with pure charcoal is to that reduced by the substance under experiment, so is the number expressing the units of heat of carbon to that of the fuel. For instance, the weight of metal obtained with pure charcoal is 34·5; allowing that with the subject of the experiment to be twenty; and taking Andrews' determination, or seven thousand nine hundred, to represent the heating power of the charcoal, while x represents the unknown heating power of the fuel; then,—

$$34{\cdot}5 \ : \ 20 \ :: \ 7900 \ : \ x.$$

Or, the heating power $x = \dfrac{20 \times 7900}{34{\cdot}5} = 4580$ nearly. If in a substance of a complex nature, such as wood, peat, coal, *et cetera*, the hydrogen and oxygen are in such a ratio as to form water by their combination, it is evident that the average result of the lead assay will approximate to the truth; but where this is not the case, and a quantity of hydrogen is present without oxygen to combine with it, the accuracy of the experiment is less to be depended on, because the heating equivalent of the former element is taken as if it were carbon, whereas it is shown by the foregoing table to be much higher. When great exactness is required, it is evident that the heating power must be determined from the elementary analysis of the substance and the estimated calorific power of the constituents. This may be done with considerable accuracy, since it does not alter the amount of heat developed, whether the combustion be effected under the influence of a concentrated stream of oxygen gas, or in ordinary air. The method of performing the calculation is very simple. Supposing the elementary composition of the fuel examined to be as follows:—

	Per cent.
Carbon,	86·48
Hydrogen,	3·04
Oxygen,	7·10
Ashes,	3·38
	100·00

it would be necessary to deduct from these numbers the oxygen, and the equivalent of hydrogen which combines with it, and to account as available for raising the temperature only the remaining hydrogen and carbon. In the above analysis the equivalent of hydrogen which will unite with the oxygen of the substance, will be $\frac{7\cdot10}{8} = 0\cdot8875$, which, when deducted from 3·04, leaves 2·1525 as the weight of hydrogen which goes to generate heat. According to ANDREWS' numbers in the foregoing table, the units of heat which this would produce may be expressed thus: $\frac{2\cdot1525}{100} \times 33808 = 727\cdot7$, and in like manner the carbon may be valued, $\frac{86\cdot48}{100} \times 7900 = 6833\cdot9$; making together $727\cdot7 + 6831\cdot9 = 7559\cdot6$ as the heating power of the fuel. In the same way may the value of any other kind of fuel be found.

Having the expression of the units of heat generated, it is easy to find the thermometric temperature which it produces; to do this, however, involves the necessity of knowing the quantity of air required for consuming the matter, and likewise the specific heat of the products. It is well known that air is composed of seventy-seven parts of nitrogen and twenty-three of oxygen, of which constituents only the latter is available in combustion. Having a knowledge of the proportionate quantity of oxygen required to burn the combustible elements, the volume of air containing this proportion may be readily found. Thus, every part of carbon combines with 2·66 of oxygen, which is yielded by 11·59 of atmospheric air; upon similar grounds, the air required for the combustion of hydrogen is 34·78 parts. In both cases, the products are carbonic acid, water, and nitrogen, the weight of which may be ascertained from the data given. Now the heat produced by the combinations of these distributes itself among the gases, so that they all indicate the same temperature, and which can be estimated, since the specific heat of these bodies is known. The number thus obtained, and which represents the temperature of combustion, varies, however, with the nature of the fuel; and still, owing, perhaps, to the specific heat of the gases at a high temperature, the results should be viewed only as an approximation.

As an example of the calculation of the pyrometrical heating power of a fuel, that already submitted may be again taken. It has been shown that the absolute heating effect of this specimen is 7559·6 units of heat, and that 0·8875 of the hydrogen contained in it is taken up by the oxygen, leaving 2·1525 of that element to undergo combustion with extraneous oxygen. It has been likewise stated that 11·59 parts of atmospheric air are required for the complete combustion of one of carbon, and, upon the same grounds, that hydrogen requires 34·78; hence the weight of air required to convert the carbon and hydrogen of the fuel into carbonic acid and water would be—

$11\cdot59 \times 86\cdot48 = 1002\cdot3$ parts for the carbon, and
$34\cdot78 \times 2\cdot1525 = 74\cdot8$ „ hydrogen;

making a total of 1077·1.

From these are produced } 326·5 parts of carbonic acid,
19·37 „ water, and
819·88 „ nitrogen, to which it
is necessary to add } 8·00 „ water, formed by the

union of the oxygen of the fuel with a portion of its hydrogen; thus making a total of $27\cdot37 = 19\cdot37 + 8\cdot0$ parts of water. The specific heat of carbonic acid being 0·221, the amount of caloric required to raise 326·5 parts 1° would be $326\cdot5 \times 0\cdot221 = 62\cdot16°$

The specific heat of aqueous vapor is 0·847; hence, } $27\cdot37 \times \cdot847 = 23\cdot18°$
the coefficient for nitrogen is 0·273; therefore, } $819\cdot88 \times 0\cdot273 = 223\cdot80°$

309·14

This number expresses the total amount of heat carried off by the products of the combustion of one hundred parts of the fuel; hence,

$$7559\cdot6 \div \frac{309\cdot14}{100} \text{ or } \frac{7559\cdot6 \times 100}{309\cdot14} = 2445\cdot3;$$

which number represents the thermometrical heating effect of one part. In this calculation the specific heat of the ash has not been taken into account; but the quantity of caloric lost in this way is so insignificant, that the results are but very slightly affected by it.

Pursuing the same course, the pyrometrical heating effect of any other kind of fuel or combustible, however numerous its ingredients, may be ascertained; that is, by finding the absolute heating power by the formula already given for the purpose, and dividing it by the sum of the specific heat of the products multiplied by their total weight, the quotient will be the available heat for any particular work when the fuel is burned.

It may here be remarked, that when a fuel is consumed in oxygen gas, the pyrometrical effect is much greater than when the combustion takes place in ordinary air, although the units of heat are the same in both cases. The difference of effect arises from the fact, that the nitrogen of the air passing through the fire in considerable quantities, renders latent a large amount of heat—the difference between the indication in oxygen and air.

The following table shows the heating effect of a few combustibles, as well when burned in oxygen gas as in air, calculated according to the above formula:—

Name.	Symbol.	Pyrometrical Heating Power. In Oxygen.	In Atmospheric Air.
Carbon,	C	9753°	2450°
Carbide of hydrogen,	$C H$	4944	2286
Ether,	$C_4 H_5 O$	4035	2070
Light carbide of hydrogen,	$C H_2$	4703	2273
Alcohol,	$C_4 H_5 O, H O$	3407	1870
Hydrogen,	H	3491	2248

It may likewise be inferred from these results—calculated from the absolute heating power of carbon and hydrogen found by ANDREWS, and from the specific heats of the products according to FAVRE and SELBERMANN—that hydrogen, which affords higher numerical results than any other combustible, as expressive of the absolute heating power, is among the worst kinds of fuel for producing a pyrometrical effect; and that carbon ranks far above it in this particular. The difference is slightly enhanced, however, in favor of carbon, by the circumstance that this element must attain a red heat before combustion occurs. The reason of this apparent anomaly with reference not only to hydrogen, but to all inflammable fuels, whether gaseous or fluid, may be traced to the circumstance, that the specific heat of carbonic acid is nearly two and a half times less than that of the weight of water generated by an equivalent of hydrogen—being only 0·221—whilst that of aqueous vapor is 0·847. The same remark equally applies to solid fuels containing inflammable matters, such as oils or gases; and hence the advantage of the preliminary charring given to wood, peat, and coal, by which the relative amount of carbon is increased in the substance.

In these calculations, reference is made only to the heating effect upon water; but in many applications of fuel, where a higher temperature is required than that of boiling water, as in metallurgical operations, *et cetera*, the pyrometrical effect of a combustible containing much hydrogen is considerably less than appears from the results stated, in consequence of the water which arises from the combustion of the hydrogen being in the one case dispersed in steam, whereas it is not so in the other. Now the quantity of caloric necessary to evaporate one part of water at 212°, is calculated from the latent heat of steam to be such as would raise five and a half parts of this liquid from 32° to 212°. All this is estimated in the calorimetrical experiments made for the determination of the absolute and thermometric heating power of the fuels mentioned in the preceding table, and, consequently, the results are much higher than would be indicated by the temperature in the furnace. It is most probable that the capacity of other gases for heat increases with the temperature, and if so, the discrepancy would be still greater. Assuming, however, that the specific heat of the other products of combustion remains the same at all temperatures, and that the water only removes the excess, the formula for correcting the results is simple and easy of application. Thus, all that is necessary is to multiply the entire amount of water resulting from the fuel, whether it be hygroscopic, or produced by the elements contained in it, or by the combustion of the hydrogen with atmospheric oxygen, by $550 = 100 \times 5{\cdot}5$, and the product subtracted from the number found in the preceding will give the pyrometrical effect.

In the following table, taken from SCHEERER'S *Metallurgie*, the results are rectified in this way, and, consequently, they afford a very good approximation to the practical heating effects of the substances mentioned. The numbers in the column of absolute heating effect are estimated with reference to the heating effect of carbon, which is taken as unity. DULONG'S determination of the heating power of hydrogen, carbonic oxide, carbide of hydrogen, and olefiant gas, has been taken as the standard in these calculations. The numbers in the column showing the pyrometrical heating power, are expressed in degrees of the Centigrade thermometer:—

	Heating Effect.		
	Absolute.	Specific.	Pyrometrical.
WOOD.			
Air-dried wood, with twenty per cent. of hygroscopic moisture,	0·36	—	1575
Kiln-dried " ten " "	0·41	—	1675
Kiln-dried wood, without hygroscopic moisture,	0·47	—	1750
White beech, air-dried,	—	0·28	—
Oak,	—	0·26	—
Oak,	—	0·25	—
Ash,	—	0·24	—
Maple, birch, bird-cherry,	—	0·23	—
Red beech, horse chestnut, elm, white-thorn,	—	0·21	—
Scotch fir, alder,	—	0·20	—
Sallow,	—	0·19	—
Willow,	—	0·18	—
Spruce fir, silver fir, larch,	—	0·17	—
Lime, aspen,	—	0·16	—
Black poplar, Italian poplar,	—	0·14	—
TURF-PEAT.			
Imperfectly air-dried turf, with thirty per cent. of hygroscopic moisture and ten per cent. of ash,	0·37	—	1575
Best air-dried turf, with twenty-five per cent. of moisture and no ash,	0·47	—	1750
Kiln-dried turf, with no moisture and fifteen per cent. of ash,	0·55	—	1975
Best kiln-dried turf, without moisture and ash,	0·65	—	2000
LIGNITE.—BROWN COAL.			
Air-dried fibrous lignite, with twenty per cent. moisture and no ash,	0·48	0·55	1800
" " " " and ten per cent. of ash,	0·43	—	—
" earthy " " " and no ash,	0·61	0·79	1975
" " " " " and ten per cent. of ash,	0·55	—	—
Air-dried lignite, conchoidal fracture, with twenty per cent. moisture and no ash,	0·69	0·83	2050
" " " and ten per cent. ash,	0·62	—	—
Kiln-dried fibrous lignite, with twenty per cent. moisture and no ash,	0·61	—	2025
The same, with twenty per cent. of moisture and ten per cent. of ash,	0·55	—	—
Kiln-dried earthy lignite, with twenty per cent. of moisture and no ash,	0·76	—	2125
The same, with twenty per cent. of moisture and ten per cent. of ash,	0·69	—	—
Kiln-dried conchoidal lignite, with twenty per cent. moisture and no ash,	0·85	—	2200
The same, with twenty per cent. of moisture and ten per cent. of ash,	0·76	—	—

	Heating Effect.		
	Absolute.	Specific.	Pyrometrical.
COAL.			
Sand coal, .. with five per cent. of moisture and five per cent. of ash,	0·79	1·06	2200
Sinter, ...	0·89	1·16	2250
Caking, ...	0·93	1·17	2300
Anthracite, .	0·96	1·44	2350
WOOD CHARCOAL.			
Air-dried black charcoal, with twelve per cent. of moisture and three per cent. of ash,	0·97	—	2450
Perfectly dried black charcoal, with three per cent. of ash,	0·84	—	2350
Air dried red charcoal, with ten per cent. moisture and one and a-half per cent. ash,	0·72	—	2200
Perfectly dry red charcoal,	0·64	—	2100
Birch, no moisture, and three per cent. of ash,	—	0·20	—
Ash, wild service,	—	0·19	—
Red beech, white beech, elm,	—	0·18	—
Red fir,	—	0·17	—
Maple,	—	0·16	—
Oak, pear tree,	—	0·15	—
Alder,	—	0·13	—
Lime,	—	0·10	—
PEAT CHARCOAL.			
Worst description of air-dried peat charcoal, with ten per cent. moisture and fifty-six per cent. ash,	0·85	—	2050
Best air-dried peat charcoal, with ten per cent. moisture and four per cent. ash,	0·83	—	2350
COKE.			
Good coke, with ten per cent. moisture and five per cent. ash,	0·84	—	2350
Best " five " three per cent. ash,	0·92	—	2400
Ditto, with no moisture and three per cent. ash,	0·97	—	2450
Sand coal coke, no moisture and five per cent. of ash,	—	0·46	—
Sinter coal "	—	0·41	—
Caking " "	—	0·33	—
GASEOUS COMBUSTIBLES.—FURNACE GASES.			
Gases from wood charcoal, A.	0·108	0·000140	1675
" " B,	0·080	0·000104	1450
Gases from coke,	0·107	0·000139	1750
" coal,	0·205	0·000267	1850
GENERATOR GASES.			
Gases from wood charcoal,	0·115	0·000150	1775
Gas from wood, I.,	0·136	0·000177	1850
" " II.,	0·124	0·000161	1575
Gas from turf,	0·092	0·000120	1525
Gas from coke,	0·110	0·000143	1775

It is assumed that the whole of the combustibles named in this table are consumed, but in practice this never happens; hence, the heating effects given are higher than would be found to result when performing actual service; further, it is taken for granted that the combustion takes place in the shortest possible period of time, and that whilst it lasts, an equal amount of caloric is evolved each instant, a condition never fulfilled in the furnace. The discrepancy produced by both these sources of error, between the practical results and theoretical calculations, is to some extent counteracted by the high temperature required to commence the combustion.

Having alluded to the process published by BERTHIER for the determination of the heating power of a fuel, the following tables are submitted as the results of his investigation; and although it will appear from what has been said in reference to WELTER's theory, that these results, from being founded upon it, are not quite correct, yet they may be useful as a close approximation to the pyrometric values of the substances mentioned:—

I.—WOOD.

Species of Wood.	Dried in the ordinary manner. Berthier.		Containing nine per cent of water. Winkler.		Perfectly dried. Schodler and Peterson.			
	Pounds of lead reduced by one pound of wood.	Pounds of water which one pound can heat from 32° to 212°.	Pounds of lead reduced by one pound of wood.	Pounds of water heated from 32° to 212° by one pound of wood.	Pounds of oxygen required for the complete combustion of one pound of wood.	Pounds of water heated from 32° to 212° by one pound.	Air at 66° Fahr. required to consume one pound of wood.	
							In pounds.	in C. F, Hessian.
Oak,	12·5	28·3	14·05	31·82	1·358	39·82	5·83	154·4
Ash,	—	—	14·96	33·89	1·356	39·76	5·82	154·2
Sycamore,	13·1	29·7	14·16	32·07	1·394	40·85	5·98	148·4
Beech,	13·7	31·0	14·00	31·71	1·346	39·44	5·78	152·9
Birch,	14·0	31·7	14·08	31·90	1·356	39·73	5·82	153·0
Elm,	—	—	14·50	32·84	1·418	41·55	6·08	161·1
Poplar,	—	—	13·04	29·54	1·390	40·72	5·96	157·9
Lime-tree,	—	—	14·48	32·80	1·429	41·87	6·13	162·3
Willow,	—	—	13·10	29·67	1·352	39·61	5·80	153·6
Fir,	14·5	32·8	13·86	31·39	1·408	41·25	6·04	160·0
Pine,	13·7	31·0	13·88	31·44	1·392	40·82	5·98	158·2
Scotch fir,	—	—	13·27	30·06	1·393	40·85	5·98	158·3
Hornbeam,	12·5	28·3	—	—	—	—	—	—
Alder,	13·7	31·0	—	—	—	—	—	—
Larch,	—	—	—	—	1·408	41·25	6·04	160·0

II.—CHARCOAL.

Species of Charcoal		Berthier		Winkler		
		Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	Air required for [illegible] combustion.
Commercial.	Poplar charcoal,	30·60	On an average 68	33·50	On an average of 75·7	On an average of 293·5 C. F. Air at 60° Fahr.
	Sycamore "	30·60		33·23		
	Ash,	29·60		33·23		
	Aspen,	29·50		—		
Enclosed in bottles immediately after being made.	Fir,	32·30	On an average 72	33·51		
	Alder,	32·40		—		
	Birch,	31·40		33·71		
	Oak,	31·30		33·74		
	Beech,	—		33·57		
	Elm,	—		33·26		
	Lime-tree,	—		32·79		
	Willow,	—		33·49		
	Pine,	—		33·53		
	Scotch fir,	—		33·62		

III.—PEAT.

Source of Peat.	Pounds of lead reduced by one pound of peat.	Pounds of water heated from 32° to 212° by one pound of peat.	
Peat from Troyes,	8·0	18·1	Berthier.
" Ham, dép. de la Somme	12·3	27·9	
" Passy, dép. de la Marne,	13·0	29·2	
" Framont, dép. de la Vosges,	15·4	34·9	
" Ischoux, dép. Landes,	15·3	34·6	
" Konigsbrunn, Wirtemberg,	14·3	32·4	
Among twenty-four sorts from Hartz Mountain, the worst gave	11·9	26.9	Winkler.
The best gave	18·8	42·6	
From Allen in Ireland.			Griffiths.
Upper peat,	27·7	62·7	
Lower peat,	25·0	56·6	
Pressed peat,	13·7	28·0	

IV.—PEAT CHARCOAL.

Source.	Pounds of lead reduced by one pound of charcoal.	Pounds of water heated from 32° to 212° by one pound of charcoal.	
Crouy sur l'Ourcq, depart. Seine et Marne,	17·7	40·1	Berthier.
Seine et Ham,	18·4	41.7	
Essone, much used in Paris,	22·4	50·7	
Framont, and peat from Champ de Fue,	26·0	58·9	

V.—BROWN COAL.

Locality.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
Gemiende Dauphin, Basses Alpes,	25·3	57·3	Berthier.
St. Martin de Vaud, Canton de Vaud,	22·6	51·2	
Minerme, department de l'Aude,	22·8	51·6	
Gardarme, Bouches du Rhône,	22·0	49·8	
Fuveau,	21·0	47·6	
Enfant Dort,	21·0	47·6	
Koep Fuarch, lake of Zarich,	20·7	46·9	
St. Lon, Basses Pyrenees,	20·3	46·0	
Val. Pineau, dép. Sarthe,	19·25	43·6	
Common German,	18·40	41·7	
Edon, dép. de la Charente,	17·0	38·5	
Alpheus, Greece,	16·3	36·9	
Triphilis, "	16·3	36·9	
Kum, "	15·8	38·8	
Elbogen, Bohemia,	18·2	41·2	
Brown coal from Meissner,	20·1	58·9	Kuhnert.
Pitch coal "	15·9	46·6	
" Ringkulh,	16·9	49·5	
" Habichtswald,	16·0	46·9	
Glance coal from Ringkuhl,	19·3	56·5	
Pitch coal from Habichtswald	19·0	43·6	
Lowest stratum, Ringkuhl,	19·0	43·6	
Middle stratum,	10·0	43·9	
Stillberger coal,	14·1	41·3	
Lignite from Meissner,	14·7	43·1	
" Laubauch,	17·5	51·3	
Earthy coal from Dax,	21·38	62·6	Regnault.
" " Bouches du Rhône,	18·89	55·3	
" " Lower Alps,	16·69	48·9	
" " Greece,	17·84	52·3	
" " Cologne,	18·24	53·4	
" " Usnach,	15·90	46·6	
Helmstadt, Prinz Wilhelm's mine,	20·17	59·1	Varrentrapp.
" other mines,	21·83	63·9	
Schöningen, Gr. Irene,	18·76	54·9	
" other mines,	18·60	54·5	

VI.—MINERAL COAL.

Locality and Species of Coal.	Pounds of lead reduced by one pound of coal.	Pounds of water heated from 32° to 212° by one pound of coal.	
CAKING COAL.			Berthier.
Coal from Dowlais, Wales,	31·8	72·0	
Glamorgan,	31·2	70·7	
Eschwiller, near Aix-la-Chapelle	31·0	70·2	
Lippe-Schaumburg,	30·9	70·0	
Newcastle,	30·9	70·0	
Carmean, near Alby,	30·1	68·2	
Rive-de-Gier, Grand Croix,	29·6	67·0	
Mons, Bouleau-Fontaine-Madame,	29·0	65·7	
Canal coal, Wigan,	28·3	64·1	
Mons, Graud-Gaillet,	28·1	63·6	
Rochebelle, near Alais,	27·6	62·5	
Bouchamp, Haute Saône,	27·3	61·8	
Bessèges, Aveyron,	27·0	61·1	
St. Pierre la Cour, near Meyenne.	27·0	61·1	
Epinac, Saône and Loire,	26·8	60·7	
From Oviedo in Asturia,	26·1	59·1	
Freuil mine, near St. Etienne,	25·4	57·5	
Bellestat, Aude—called jet,	24·4	55·2	
Jet—locality unknown,	23·3	52·8	
SINTER COAL.			
Cherry coal, Derbyshire,	27·2	61·6	
Soft coal,	26·3	59·5	
Oviedo in Asturia,	26·1	59·1	
Cannel coal from Glasgow,	24·9	56·4	
St. George's de Lavencas, Aveyron	24·0	54·5	
Cannel coal from Lancashire,	23·5	53·2	
Ombrowa, Silesia,	21·2	48·0	
Salin, Jura,	21·0	47·5	
Vagas, Slavonia,	19·4	43·9	
SAND COAL.			
Durham,	31·6	71·6	
Rolduck, near Aix-la-Chapelle,	31·0	70·2	
Zinsweyer, near Offenberg,	22·2	50·3	

VII.—COKE.

Species of Coke.	Pounds of lead reduced by one pound of coke.	Pounds of water heated from 32° to 212° by one pound of coke.	
A la Garre, from coal of St. Etienne	28·5	65·6	Berthier.
From coal of Bessèges,	28·4	64·3	
" Rive-de-Gier,	26·0	58·9	
Gas coke from Paris,	22·0	50·3	

VIII.—ANTHRACITE.

Locality.	Pounds of lead reduced by one pound of anthracite.	Pounds of water heated from 32° to 212° by one pound of anthracite.	
Anthracite, from Lamure, near Grenoble,	31·6	71·5	Berthier.
Anthracite from Pennsylvania,	30·5	69·1	
From Laval, la Chaumière,	33·0	74·7	
From Laval, la Baconière,	26·6	60·2	
" Corbattière in Savoy,	26·7	60·5	

The numbers cited in some of the preceding tables, as indicating the heating power of many kinds of fuel, appear at first sight contradictory to the known results obtained with such materials in the furnace. Thus considerably more heat is produced, judging from the work performed, when hard woods are burned than with the softer varieties; but numbers stated in the tables assign the greater heating power to the softer woods. Schödler and Petersen account for this apparent inconsistency by the difference in the amount of hydrogen producing unequal intensity of combustion in the two cases. They show that whilst woody fibre contains oxygen and hydrogen in the proportion in which they unite in water—that is, in the ratio of eight to one—all woods have the hydrogen in greater or less excess of the oxygen, and this excess acting at the temperature of combustion upon the carbon of the substance, produces a quantity of hydrocarbon gases, which are rapidly consumed. The residuary charcoal becomes in this case more porous, and, therefore, presents a larger surface to the oxygen of the air; the consequence of which is, that it is much more speedily consumed than if it remained a dense compact body. Hard woods have less hydrogen than the soft ones, and this fact accounts for the difference in the amount of heat produced. The annexed table gives the excess in one thousand parts after the oxygen has been assimilated:—

	Excess of hydrogen.
Ash,	5·05
Oak-wood,	5·08
Beech-wood,	6·50
Willow,	7·00
Birch,	7·50
Scotch fir,	7·70
Poplar-wood,	8·20
Maple,	8·30
Pine-wood,	8·80
Deal,	9·50
Elm,	10·00
Lime-wood,	13·90

In the other tables above given, it will be seen that the highest place is assigned to lime-wood in point of heating power; but, in practical application, the oak produces a better result. The difference of the time required for the combustion of the two accounts for the inequality. In the case of lime-wood, a considerable quantity of its carbon is taken up by the large excess of hydrogen, and is given off in the shape of inflammable gas, which presents an extended surface to the oxygen, and is consequently speedily consumed; the residuary charcoal burns rapidly on account of its porous nature, arising from the evolution of the particles of hydrogen and carbon. Now, oak-wood not having so large a per centage of hydrogen to react upon its carbon, of course a greater weight of the latter remains, and this being denser than in the case of lime-wood, a less surface is undergoing combustion in the fire, and a longer time will be occupied in its burning. It rarely happens that the arrangements for the application of caloric in the arts are of such a nature as to allow of the entire economization of the heat produced, more especially when it is developed intensely and in a short space of time; hence, when soft woods are employed as fuel, there is a considerable amount of heat lost, by which the working effect is lessened. On the contrary, with woods which burn slowly, the loss is not so great, since it is nearly wholly absorbed in proportion as it is developed by the combustion. The same remark applies to coals; and this is the reason why particular kinds are employed for steam-generating purposes, for glass and porcelain works, *et cetera;* but although there appears a very great difference arising from this cause, yet it does not follow that the pyrometric effect of the one is less than that of the other. If, for instance, two equal weights of oak-wood be consumed—one in the form of chips or shavings, and the other in a compact mass—it will be seen that the former will burn in a much shorter period than the latter, and that the practical heating effect produced by the one will be much less than by the other. It is evident that the pyrometric heat is the same in both, only that the evolution of caloric from the divided portion is so rapid as to cause the dissipation of a large part of it. Where a high temperature is necessary, it is evident that a fuel capable of giving off its caloric in a comparatively short space of time is required; and hence the preference given to soft wood, or finely cleft hard wood, in the glass furnace and porcelain kiln. The facility which minute division affords for rapidity of combustion has, however, its limit, which, when exceeded, instead of expediting, retards, and when carried to extremes, actually arrests combustion entirely, as may be observed with coal, coke, wood, and peat charcoal, when crushed to a powder. In this case the air has no access to the combustible except at the surface, so that the area of contact is very limited when compared to the bulk, and, consequently, ignition is arrested. When it happens that fuel in this minutely divided state is the only kind available, the combustion is assisted by piling blocks of limestone, sandstone, or other material upon the grate, and placing the fuel—such as sawdust, slack, brees, *et cetera*—upon them, in which case the currents, ascending through the interstices, supply the requisite oxygen to the fuel. If the grate does not admit of this arrangement, the finely-divided combustible is converted into a valuable compact fuel by blending it with tar, pitch, or some such binding material, as described under Patent Fuels.

In consequence of the defective furnace arrangements in most manufacturing establishments, the quantity of heat absorbed and utilized bears, in general, no definite relation to the quantity produced, without taking into account the proportion of the fuel, which is either not at all, or only partially burned. The loss from these two causes alone has been estimated to be equivalent to the one-half of the coals consumed under the imperfect systems generally followed. Of late years considerable attention has been directed to discover some means whereby the cause of the first loss might be removed by an improved construction of the furnaces or fire-places, with a view to their better retention of the heat, and marked benefits have arisen to many branches of trade, but more especially to those making extensive use of steam, from the various investigations instituted. Although the waste of caloric from both the causes mentioned—namely, the non-retention of the heat and the imperfect combustion of the material—is very great; yet a considerable waste of fuel is occasioned by other circumstances which attend ordinary combustion, and which require investigation as much as the others. To enter into a minute discussion of all these would be tedious; but a short examination of the principal ones will be necessary, to point out the sources of the difference between the calculated value of fuel in heating power, estimated from experiments controlled in such a way as is not possible when the materials are burned in the ordinary furnace or grate, and that which results in practical operation.

In the first place, it will be evident that the mere maintaining of a fuel in a state of combustion, whether in a grate or furnace, involves, and is dependent upon, a certain loss of caloric, as well latent as sensible, in the production and expansion of the gases resulting from the change, whereby they ascend from the substance and admit the fresh air to keep up the chemical action. It is well known that, under the provision made for burning fuel of any description, the air which is admitted must always be greater than the amount which theory assigns as sufficient, otherwise the combustion would be imperfect, and a heavy loss sustained. Admitting, however, that no more than is absolutely necessary passes through the fire, it will be seen, on reflection, that still a great amount of heat is rendered useless by the draught in the chimney. From the tables already given, it appears that for the complete combustion of one pound of dry wood an average of 5·94, or in whole numbers, six pounds weight of air at 32°—equal one hundred and forty-eight cubic feet—are required. Admitting that this volume of gaseous matter passes off from the fire to the chimney at a temperature of 300°, the whole heat lost will be 1620°—(6 × 270)—or as much as is equivalent to raise nine pounds from 32° to 212°, and, therefore, as would effect an equal increase of temperature in 2·4 pounds of water. Schödler and Petersen have shown that one pound of dry wood raises 40·6 pounds of water from 32° to 212°; hence the loss sustained, in consequence of the heat which is carried into the chimney, is $\frac{2·4}{40·6}$ = ·06, or six per cent. It seldom happens, however, that the temperature of the escaping gases is so low as that assumed in this instance; and where their heat is greater, of course, the loss will be proportionally increased; and the same effect will follow when the quantity of air passing through the furnace is greater than the theoretical amount.

Another cause of the reduction of the heat, and the prevention of a due effect resulting from combustion in the furnace, is the water which is usually present in fuels in greater or less abundance. The loss suffered from this alone is twofold: firstly, inasmuch as the amount of real combustible is diminished by it, whether it be large or small; and, secondly, because by its conversion into steam, in which state it passes off with the products of combustion, it unites with a large amount of caloric, which becomes latent.

When the proportion of water is appreciable, the quantity of caloric which is given off is very great. Wood, for instance, contains, after being dried in air, about one-fifth of its weight of moisture, so that when employed in this state as a fuel, only four-fifths of the weight taken is capable of generating heat. Supposing that 40·6 pounds of water are heated from 32° to 212° by one pound of wood perfectly free from moisture, it is evident that only 32·5 pounds would be brought to the same degree by the available fuel in the pound of common air-dried wood. Further, the one-fifth of moisture is expelled in steam, and this takes up as much caloric as would bring 5·5 pounds of water from the freezing to the boiling point. Founding a calculation upon this fact, the one-fifth of a pound of water present would assimilate as much heat as would raise 1·1 pound of water to the boiling point. By adding both, the total loss will be 9·2—8·1 + 1·1—or 22·5 per cent. less than if dry wood were employed. This example shows, in a striking manner, the great advantages which the employment of wood, peat, lignite, or such fuel as is liable to be more or less saturated with hygroscopic matter affords, when they are thoroughly exsiccated, over the same when containing ten, fifteen, or twenty per cent. of moisture. Where wood is much employed, care is taken to submit it to a preliminary drying operation, so that its combustion may be rapid, and that the loss described may be avoided.

It may be remarked, however, that water does not, under all circumstances, diminish the calorific effect of a fuel; but on the contrary, when judiciously managed, adds to it in a high degree. Bunsen and Fyfe have shown that aqueous vapor passed over incandescent fuel suffers decomposition; its oxygen is abstracted by the highly heated carbon, and carbonic oxide results, while the hydrogen passes off partly uncombined, and partly associated as carbide of hydrogen. These three products in the presence of sufficient oxygen, and the high temperature of the furnace, are capable of undergoing further combustion, and yield a large amount of heat by being converted into carbonic acid and water. In numerous experiments it was shown that the caloric developed in this manner, more than compensated for the fuel employed in producing the gases. The application of aqueous vapor, however, demands caution; for when used in too great an excess, it reduces, rather than increases the temperature of the fire. Its effect is to diminish the heat, unless used sparingly, and with a free admission of air to promote the combustion of the inflammable gases.

The method in which water is utilized for raising the temperature, is to place a vessel of this liquid beneath the bars, so that the heat radiated downwards may have the effect of producing the steam without further trouble; where steam-engines are employed, a jet of the waste vapor is allowed to issue under the furnace. A mistaken inference from this fact leads many to moisten the coals before throwing them on the fire, with a view to the increase of the heat; but that the contrary effect is produced, is evident from what has been already detailed; the water in this case serves only to slacken the combustion, and render a considerable amount of heat latent. It is the practice, especially, to moisten small coals and slack, when it is required to burn them on the furnace bars, and in this case the loss in heat from the presence of the water may to a certain extent be compensated by the advantage of the adhesion produced between the particles of the fuel, whereby it is prevented from falling into the ash or stoke-hole. Clay, plaster, or bituminous substances would serve better.

Besides the loss of caloric which results from the gases or products of combustion passing in a superheated state into the chimney, as well as from the presence of an excess of moisture, there is another source of loss which is of far greater importance, and which is much more generally felt. It is necessary for keeping up the ignition that the column of air in the chimney be expanded by heat, and thus rendered specifically lighter than the surrounding atmosphere, to produce a constant current through the fire. The moisture in a fuel may be removed by a preliminary desiccation, the extent of the heat-absorbing surface may, under certain circumstances, be augmented, so as to arrest and economize a large amount of caloric which might otherwise be lost; but to effect a complete combustion of the fuel, with the least possible volume of air, demands a thorough knowledge of the scientific principles involved in this change, as well as of the products resulting therefrom, together with the strictest attention on the part of the *stoker*. It is evident that a definite relation must exist between the weight of combustible elements in a fuel, and the oxygen which is required to convert these into carbonic acid and water, and that to effect the latter change within the limits of this relation requires the most favorable circumstances, such as properly arranged furnaces, the adjustment of the fuel and draught of air passing through the fire, with skill and constant attention on the part of the fireman.

In a grate of any given dimensions, and burning a given weight of fuel in a determinate period, the quantity of air to be supplied can be easily deduced with the aid of known experimental results, as well as from theoretical calculations. Thus, according to the determinations and analyses quoted at page 112, one pound of peat requires for complete combustion from seventy to one hundred and thirty-four cubic feet of air at 66·2°; medium kinds of this fuel, one hundred and forty-nine cubic feet; one pound of peat charcoal requires one hundred and fifty-five to two hundred and twenty-eight cubic feet; one pound of brown coal, according to the lead test, one hundred and thirty-nine to two hundred and twenty-two cubic feet, and by analysis, one hundred and sixty to two hundred and forty-eight; one pound of coal requires, by the lead test, one hundred and seventy to two hundred and seventy-nine, average qualities two hundred and twenty-eight cubic feet; according to RICHARDSON'S analysis, from two hundred and forty-eight to three hundred and three; by REGNAULT'S, average qualities, from the coal formation, take three hundred and twenty to three hundred and thirty-two—those from the secondary formation, two hundred and ninety-three to three hundred and twenty-six cubic feet; one pound of coke requires one hundred and ninety-four to two hundred and fifty cubic feet; one pound of anthracite, according to the lead experiment, demands two hundred and thirty-three to two hundred and seventy-seven—according to REGNAULT'S analysis, three hundred and twelve cubic feet. A cubic foot of air weighs 0·03794 pound Hessian—0·07500 English—at the above temperature.—*Richardson and Ronalds.*

Now, in these calculations, it is presumed that the oxygen of the air is in contact with every particle of the fuel during ignition. Could the same condition be insured in the furnace, it is evident that the great desideratum required in combustion would be attained; no escape of combustible gas could then ensue, nor of the carbonaceous particles which give to the gases passing up the chimney the character of smoke; and the greatest possible heat arising from the burning of the substance in air would be developed. Indeed, nothing would be wanting to extract from the fuel the benefit of its total theoretical heating power, but such an arrangement of the furnace as would perfectly utilize the caloric so produced. No one, however, who has any experience as to the manner in which the fire is managed in the ordinary kinds of furnaces, will hesitate to assert that the above conditions are never supplied. The coals are thrown in thick layers upon the grate, by which the existing temperature for a time is greatly depressed, being absorbed in part by the cold fuel, and by the dispersion of its hygroscopic matter. In addition to the reduction of the heat temporarily, the thick bed of fuel impedes the draught, and sufficient air cannot enter to effect a consumption of coals, adequate to the generation of the amount of heat required. The portion of air which traverses the fire is deoxidized by the ignited fuel on the bars, and no oxygen, for a considerable period, can come into contact with the mass lying upon that which is burning; but although in this way it does not contribute to the pyrometrical effect, the temperature of the ignited mass, and the heated gases permeating it from below, cause a distillatory change, by which the whole of the available hydrogen, together with a large per centage of the carbon, is expelled as hydrocarbon gases, which escape combustion. This decomposition, occasioned by the undue fuelling, does not only waste the combustible matter in the way alluded to, but it diminishes the heat which is produced by the portion that burns, since the gases in passing off carry with them a considerable portion of caloric as latent and sensible heat. Further, after the distillation of the gaseous matter is effected, and the residuary coke has acquired incandescence, an additional loss is sustained in consequence of the carbonic acid in which the combustion of the carbon in the base of the fire terminates, being, by the deoxidizing power of the overlying glowing combustible, transformed into carbonic oxide, the abstracted oxygen taking as much again of the carbon as it would do if perfect combustion had occurred. The double volume of gas produced under these circumstances renders a large quantity of heat ineffectual for useful application.

It is thus that three radical and distinct sources of loss arise out of the profligate system of stoking usually practised; namely, waste of the volatile inflammable hydrocarbon gases of the substance; loss of the fixed carbon by the deoxidation of the carbonic acid; and, lastly, loss of the caloric with which the combustible and non-combustible gases combine and carry off, as well in the state of latent as of sensible heat.

Independently of such gross waste in the application of fuel, another of no little moment exists—namely, the rapidity of the draught in the flues. Experiments have shown that in those cases where the flue has been lengthened with the view of affording a greater heating surface, the effect produced was materially affected by having the damper entirely withdrawn, or only partially so. Such a result is a natural one, considering the imperfect conducting power of air, and also of water, when it is on the point of passing into the state of elastic vapor; for the one does not transmit the caloric to the fluid, nor does the latter combine with it so readily as to sufficiently abstract this principle from the gases when they rapidly circulate around the boiler and pass away. Ure illustrates this non-conducting quality of gases passing rapidly over a conducting surface by the slight elevation of temperature which is experienced in guns, cannon, *et cetera*, notwithstanding that the temperature produced by the combustion of the powder is very high. The reason is, that the rapid evolution of the gases prevents the absorption of the caloric by the metal. In the case of a furnace, the barrel of the gun may be represented by the flue; the force of the explosion, and the products therefrom, by the draught and vapors produced in an ordinary furnace; and the effect of non-absorption in the latter instance, will be as marked as in the former if the draught be too great. Hence it will be readily inferred, that to absorb the whole or the greater part of caloric, time must form an important consideration to afford a more or less prolonged contact of the heated gases with the material of the boiler; consequently, where the draught is increased rather than checked within proper limits, the pyrometrical effect is, to a considerable extent, lost.

The causes of these losses in the production of heating effect, and, consequently, of mechanical power, have of late years engaged much attention, as well in America as in this country; and although the investigations, which have been conducted with a view to ascertain the conditions by which the largest amount of work might be performed by the fuel, have added materially to the knowledge of those circumstances that affect the heating power, they have scarcely touched upon those which relate to the economizing of fuel. Several modifications of furnaces have been patented of late years for the prevention of smoke, while, at the same time, it is alleged that the heat of the fire is increased; but it is to be feared that many of these arrangements, while ostensibly obviating one evil, produce others quite as injurious. This arises for the most part from the injudicious introduction of cold air at a part where the temperature is too low to cause combustion of the inflammable vapors and portions of carbon; or the quantity of air admitted is too great, and the heat rendered latent by it amounts to as much or perhaps more than in the ordinary fire. Much benefit will doubtless accrue from those improvements in the furnace by which the supply of fuel upon the grate is regulated, and rendered more or less independent of the stoker. By these the loss arising from imperfect combustion, as already explained, is to a great degree avoided. To enter into a discussion and notice of the several improvements would be, in some degree, foreign to the subject of this article; but the reader who may be desirous of information on this matter, is referred to a work by Mr. W. Wye Williams, to the *Dictionnaire des Arts et de Manufactures*, published by Laboulaye, and to Knapp, Ronalds, and Richardson on *Fuel*.

Regarding the investigations above alluded to, the chief object with which they were undertaken was to find the best coal for steam navigation. As already mentioned, there are many kinds of coal, which, though capable of producing a high temperature during combustion, yet are not economical for the purposes of the navy or other boiler furnaces. The reasons have been already stated. To find the best among the numerous varieties of coal extracted even from the same pits, and still more from different fields, the Government of the United States intrusted Professor W. R. Johnson with the investigation. This example was soon followed by Great Britain, whose manufacturing and naval interests, depending so much on steam, rendered such an inquiry most urgent. Dr. Lyon Playfair and Sir Henry de la Beche were appointed as the principals in this research. In both the American and British investigations, the experiments were made with reference to the following principles:—

Firstly. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words, it should be able to produce a quick action.

Secondly. It should possess high evaporating power—that is, be capable of converting much water into steam with a small consumption of coal.

Thirdly. It should not be bituminous, lest so much smoke be generated as to betray the position of vessels of war when it is desirable that this should be concealed.

Fourthly. It should possess considerable cohesion of its particles, so that it may not be broken into small fragments by the constant attrition which it may experience in the ship.

Fifthly. It should combine a considerable density with such mechanical structure that it may be easily stowed away into small space—a condition which, in coals of equal evaporative values, often involves a difference of more than twenty per cent.

Sixthly. It should be free from any considerable quantity of sulphur, and it should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

The boiler employed by Johnson in his trials of the evaporating power of coals, was thirty feet long, and three and a half in diameter; this was set over a furnace, and the heated gases, after passing through two interior return flues, each one foot in diameter, escaped by the side flues exterior to the boiler to the chimney, making the entire length of circuit for the products of combustion one hundred and twenty-one feet. The grate surface was sixteen feet and a quarter, and the area of heat-absorbing surface three hundred and seventy-seven and a half square feet, so that the ratio of both surfaces was as one to 23·2. The chimney was sixty-three feet high, and had a cross section of three hundred and twenty-four square inches.

On the other hand, a Cornish boiler was employed in the English investigation, the length of which was twelve feet, with an external diameter of four feet. The furnace, as usual with this class of steam boilers, was constructed in a flue two feet in diameter passing through the middle of the vessel. After the products of combustion traversed the central flue, they returned by two other external side ones to the front, and thence entered a main under the boiler, and which led to the chimney, thus making a course of thirty-six feet. A grate five feet square was employed, and the absorbing surface amounted to 197·6 square feet, so that the latter was to that of the fire as 1 to 39·5. In this case the height of the chimney was 35·5 feet, and its cross section presented an area of 182·25 square inches.

The amount of coals consumed in the hundred and forty-four trials made by Johnson at Washington was sixty-two and a half tons; and, in the eighty-two experiments conducted at London by Playfair and de la Beche, about fourteen tons six hundred. The average weight of coals burned in the American inquiry at once was eight hundred two quarters twenty-six pounds, and in the English, three hundred two quarters.

The results of these experiments were published by Professor Johnson in a Report to Congress in 1844, and by Sir Henry de la Beche and Dr. Lyon Playfair in a series of Reports to the British Government, concluded in 1851; but the relation between the composition of the coal, as ascertained by analysis, and its value for producing steam, is not by any means very clearly brought out even by these experiments. They prove, indeed, by the very differences which they exhibit, as compared with the results of experience, that the only trustworthy method of determining the value of a fuel, especially for steam purposes, is that of practical experiment under the boiler, where several tons and not pounds are consumed. It appears, therefore, to be unnecessary to transcribe the voluminous and elaborate tables embraced in the American and English reports, which the few readers who may be desirous to inspect them will find in Ronalds and Richardson's *Chemical Technology*. It may be stated, however, that in Johnson's experiments the weight of water evaporated at 212° from one cubic foot of coal was found to vary from 440·8 to 556·1 pounds with different specimens of anthracite; from 350·2 to 478·7, with bituminous coking coal; and from 353·8 with Scotch, to 439·6 with English bituminous coal. In the English experiments, the Newcastle coal varies from 325·24 to 529·34; and Scotch coals from 352·58 to 460·82. The following may be given as a summary of the latter series of experiments, where A represents the evaporating power, or number of pounds of water evaporated at and above 212° by one pound of coal; B, rate of evaporation, or number of pounds evaporated per hour; C, weight in pounds of one cubic foot of coal, as used for fuel; D, space occupied by one ton in cubic feet; E, results obtained in experiments on cohesive power of coals, or, in other words, the per centage of large coals; and F, the per centage amount of sulphur contained in the coals:—

	A.	B.	C.	D.	E.	F.
Average of thirty-seven samples from Wales,......	9·05	448·2	53·1	42·71	60·9	1·42
" seventeen samples from Newcastle, ...	8·37	411·1	49·8	45·3	67·5	0·94
" twenty-eight samples from Lancashire,..	7·94	447·6	49·7	45·15	73·5	1·42
" eight samples from Scotland,..........	7·70	431·4	50·0	49·99	73·4	1·45
" eight samples from Derbyshire,........	7·58	432·7	47·2	47·45	80·9	1·01

The volume of the coals with reference to their respective qualities as a solid compact fuel was tested by Johnson, in the state in which they come to market, but in the English inquiry the several varieties were broken up into fragments not exceeding one pound in weight; hence the results in the latter were necessarily more uniform than in the former, and, therefore, the quantity of steam raised by equal bulks of the coal would from this, if from no other circumstance, be in favor of the English coals. Where the specific bulk of a fuel becomes a matter of consideration, as it must do when required for shipping, attention should be devoted to the size of the lumps, for even with the same coal there is great difference in the weights of two given volumes, one of which is in large and the other in smaller pieces.

The moisture present in the British coals was not deducted in calculating their evaporative value, as it was considered of greater practical importance to estimate this in the state in which they were found in the market.

The British commission, besides employing the direct practical method—that of burning a portion of the coal under the boiler—had recourse for the calculation of the value of the fuel to the lead test, as also to the ultimate analysis. Between the results of these three methods there is often to be found in their tables a considerable difference, amounting even to a virtual contradiction. This has been shown to arise from the almost utter impossibility of economizing the heat under the boiler in the practical test, and from the fact of the oxygen derived from the litharge being made the basis for calculating the pyrometrical effect of the fuel in the lead test, an assumption that has been shown to be erroneous.

It is at least certain that very different quantities of steam were found to be raised by coals capable of reducing the same amount of lead, and hence it is evident that the lead test cannot be relied on as an exact measure of the value of a fuel, although it may afford an approximation. The same observation applies to the method of testing by the estimation of the coke or fixed carbon, the amount of which does not present a sure guide in the determination of the value of coal, since a wide difference was found between the steam generated or work done by different coals possessing an equal average amount of carbon.

With respect to the value which ought to be attached to the experimental results obtained by actually burning a portion of coals under the boiler, the information which even this method affords for practical guidance is not so reliable as might appear at first sight. This arises from the circumstance, that the effect of the fire depends to a great extent on the form and setting of the boiler; and as marine boilers differ from the Cornish ones in these particulars, the numbers found in the course of the experimental investigation do not present the actual equivalent of work to be expected in steamships. Even from the smallness of the boiler employed in the experiments, the results fell short by twenty per cent. of the maximum amount of work which the same fuels could perform when applied to larger boilers constructed and set on the same principles. The inquiry is rendered less efficient from another cause, namely, the want of a thorough control and measurement of the air passing through the furnace; for, doubtless, a knowledge of this would be of immense service in the application of fuel, so as to develop its entire pyrometrical effect under the most favorable circumstances.

The Editor concludes this article by acknowledging his obligations for much assistance to the very able work of Richardson and Ronalds already referred to, as likewise to Miller's *Chemistry*, Dumas' *Traité de Chemie Appliquée aux Arts*, and Dr. Ure's *Dictionary*.

GAS.—*Gas*, French; *Gaz*, German.—A recent writer appositely remarks, that in the present era, when the creative faculty of man seems to be more than ever busy in its obedience to the primitive injunction to subdue the earth, it seems but to be consistent with the harmony and order of the world that the production of light should have been one of the earliest aims of British industry. For the daily experience of social as well as of organic life, declares light to be one of the chief necessaries of man, no less than of every other living thing; and sense and science alike at once accept as truth, that light was the first material force that worked in the embryo universe.

From the tallow dips of the last generation, powerless and void of everything save smell, to the bright stearic acid that cheers the drawing-room now-a-days, what a development! In the iron arteries under towns, in the constellations of burners that rule the nights of favored days, rising over the chaotic oil-lamps of old, what a creation! And can any one doubt that the same voice which first bade light to be, has summoned gas to the service of man, and pronounced the light from it to be good?

The discovery and earliest observation of elastic aëriform fluids, capable of being inflamed and of imparting light and heat, must, according to Hughes, undoubtedly have been of great antiquity. The most ancient writings contain notices of inflammable vapors springing from fissures and cavities in the earth. It is evident, therefore, that gas being a natural production, no such individual as the discoverer and inventor of gas ever existed. Modern chemistry will have no difficulty in showing that all inflammable gases, whether arising naturally from rocks, or produced artificially by combustion or otherwise, are composed of simple elements, which present a remarkable analogy to the common bihydride of carbon, the gas chiefly consumed in our street lamps and houses at the present day.

Inflammable gas may be truly said to be as old as the first creation of organic matter, for wherever animal or vegetal substances have existed, by the immutable laws of nature they have been subject to eremacausis, and wherever decomposition has taken place, a variety of gases has been produced, some of them combustible, and others not. Whether the change be that engendered by the slow combustion of decay, or that more speedy process caused by the application of sensible heat, the effect is the same—the gases are equally produced in the two cases.

Gas may, in one sense, be called a more natural production than steam, although the latter has existed from the first creation of water, and in its palpable state, as proceeding from boiling water, must have been observed in all ages.

The *discoveries* of man in respect to gas and steam, ought rather to be called *applications:* they are conquests over the elements, the subjugation of great powers in nature to his use and convenience. So it is with nearly all great inventions, in which is found one power of nature after another, chained, confined, bound down, stored, and then let loose when required, and made to work machines, to propel ships across the ocean, to supply the place of human exertion itself in a thousand different ways; nay, to pass far beyond the actual powers of the combined labor of multitudes, and to effect that by a single effort which the manual strength of a world could scarcely accomplish.

If such astonishing applications of steam and gas had been made in the days of ancient Greece, what magnificent, expressive, and high-sounding names would have been found to convey their meaning! Instead of such contemptible little monosyllables as *gas* and *steam*, one might have heard of the spirit of coal and the spirit of water, with some superlative adjective to stamp the vast importance of each. In such an age these wonderful conquests would have thrown all meaner efforts into the shade; for them alone would poetry have strung its harp, and the grandest epic productions of genius might have commemorated the victory of man over the inanimate matter of nature, instead of dedicating her loftiest songs to the art of war.

As already stated, jets of flaming gases bursting out from the ground have attracted notice from a very early date, so that savage tribes, owing to the grandeur of the spectacle, apparently unsupported by fuel, considered the spots whence such emanated as the abodes of their gods. The well-known holy fires of Baku still burn, and are due to the ignition of light carbide of hydrogen with some naphtha vapor. They are worshipped by the savages in the neighborhood of the Caspian Sea. In China, the borers for salt water often meet with streams of combustible gases, which they employ for illuminating factories and evaporating brines; consequently, the Chinese were acquainted with the use of coal-gas, long before the knowledge of its application was acquired by Europeans. The most familiar instance of the elimination of inflammable gases from the earth in this country, is the fire-damp of the miners; but it is not of such a good quality as that artificially produced.

Some of the earlier nations considered fire as a type of divinity, and one can scarcely wonder at the feelings of veneration occasioned by mysterious outbursts of flame, the origin of which appeared utterly incomprehensible. Hence superstition erected her altars over such flames, and claimed the interference of the gods to sustain the perpetual miracle. But all that had been observed with reference to inflammable vapors in olden times, was very far indeed from leading to any attempt to collect and use them. Their very nature and composition were unknown, and the most mistaken ideas prevailed as to their real elements. It was not until modern chemistry had exploded volumes of ancient dogmas, had traced the so-called elements to far simpler forms, and had taught the laws according to which simple bodies are combined in order to constitute all forms of matter—it was not till then that it began to be seen that the inflammable vapor of coal, wood, oils, and other fatty substances, was analogous with the marsh gas which arises in bubbles from the decomposition of vegetals under water; that it was of the same nature as the *ignis fatuus* or *Will-o'-the-wisp*, which on the wild moor or bog has lighted many a traveller to destruction; finally, that it was nearly the same as the gas which arises from the decomposition of water, however effected; and that, in fact, one of the constituents of water, the greatest antagonist and extinguisher of flame, was itself the most inflammable substance in nature, namely, hydrogen gas; while oxygen, the other element, is the greatest supporter of combustion.

Various opinions have been hazarded to account for the almost perpetual fires which were kept burning on the ancient altars. These are mentioned by STRABO and PLUTARCH, who add that when they happened to be extinguished, they were lighted by invisible means. The altar in the temple of Ægina may be mentioned as affording a good explanation of the mystery. Here a round hole, about thirteen inches in diameter, is observed in a block of stone. The circular orifice opens into a square one, which passes down through solid stone to a depth of several feet. The lower extremity of the square hole communicates with a cavity in which Mr. DODWELL supposes a fire to have been constantly kept burning, so that the flame did not appear above the surface of the fissure. He says, nothing more would be necessary than to pour oil into the orifice, when the flames would immediately burst forth, and appear to have a miraculous origin.—*Hughes.*

Although the application of the gases produced by the destructive distillation of pit-coal, as a means of obtaining artificial light, appertains to modern times, yet the germ of it may be traced back nearly two centuries. In the year 1659, THOMAS SHIRLEY is said to have attributed the exhalations from the burning well of Wigan, in Lancashire, to the subjacent coal beds; and in 1664, the observation was made by Dr. CLAYTON, that combustible illuminating gas was formed during the decomposition of coal by heat, and that this could be collected.

One hundred years afterwards application was made of the fact, but by mere accident. In 1787, Lord DUNDONALD, of Culross Abbey, in Scotland, took out a patent for making coal-tar, and erected near the Abbey a series of ovens for this purpose. The tar was conducted by pipes from the condensers into cylinders of brickwork, each of which had a small opening at the top for the escape of the incondensable part of the products. To these openings the workmen were in the habit of attaching a cast-iron pipe by means of a mass of soft clay, and lighting the gas at the other end to give them light during the darkness. His lordship, also, was in the habit of burning the gas in the Abbey as a curiosity; and, for this purpose, he had a vessel constructed resembling a large tea-urn, which he frequently caused to be filled and carried up to the Abbey to light the hall with, especially when he had company with him.

But the true discoverer of the practical application of coal-gas for lighting purposes was Mr. MURDOCH, a Scotchman, who, in the year 1792, while at Redruth in Cornwall, made a series of experiments on the quantity and qualities of the gases produced by distillation from different mineral and vegetal substances. He was induced, by some observations which he had previously made on the burning of coal, to try the combustible properties of the gases produced from it, as well as from peat, wood, and other inflammable substances; and was struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light, and the facilities of its production. He continued his experiments till 1798, when he removed from Cornwall to a situation of importance in BOULTON and WATT'S works at Soho, and there he constructed an apparatus which, during many successive nights, was applied to the lighting of their principal building. In the meantime he tried various methods for washing and purifying the gas, and these experiments were continued with some interruptions till the peace of 1802, when a public display of the gas-light was made by him in the illumination of the manufactory at Soho on that occasion. He afterwards extended the same apparatus, so as to give light to all the principal shops in the neighborhood, where it was in regular use to the exclusion of other artificial light; and, finally, in 1808, he fitted up the gas apparatus in Messrs. PHILLIPS and LEE'S cotton mill; from which time it gradually extended to all the cotton mills in the kingdom.

At the same time, much credit is due to Mr. WINSOR, who took out a patent for a similar process in 1806, delivered lectures on the subject, and endeavored to get up a joint-stock company for street-illumination. In this object he did not succeed till 1812, when some of the streets of London were first lighted with gas. Oil-gas was first prepared on a large scale by PHILIP

TAYLOR, who erected the gas-works at Paris soon after the peace of 1815.

NATURE OF ILLUMINATING GAS.—KNAPP justly remarks that the lighting properties of a gas, or mixture of gases, must depend upon the relation which the carbon in it bears to the hydrogen, and that it can only be turned to a useful purpose when there is more of the former of the two elements present than in fire-damp, and when the proportion of both approaches that of olefiant gas. Light carbide of hydrogen—CH_2—contains 75·4 carbon to 24·6 hydrogen; olefiant gas—C_2H_2—consists of 86 carbon to 12 hydrogen.

The illuminating power of different carbides of hydrogen varies considerably. Fire-damp contains one part by weight of hydrogen to three of carbon; but one part of hydrogen requires eight, and one part of carbon 2·666 parts of oxygen for combustion; now, supposing the oxygen of the air, which performs an important part in combustion, to combine with both simultaneously—then, as eight parts of oxygen consume one of hydrogen, just eight parts of oxygen would unite with the carbon, and consume three parts, or exactly the whole quantity. In olefiant gas, there is one part of hydrogen to six of carbon; therefore, under the same supposition, one part of hydrogen and three parts of carbon will be consumed together, whilst as much carbon, or three parts, will be set free. Although in reality the hydrogen is always consumed first, yet it is obvious that olefiant gas is capable, under similar circumstances, of supplying more carbon to the flame, and, consequently, of producing more light, and it would have a decided preference above all others, if it could be procured sufficiently cheap. This, however, is not the case, and one must be satisfied, from economical motives, with a mixture of gases, or, in other words, a compound gas, produced by the decomposition of certain substances of organic origin, and containing so much olefiant gas that it far exceeds carbide of hydrogen in illuminating power. When these organic substances are exposed to a certain temperature, the following process results. Certain volatile products escape, which partly condense on cooling into tar and aqueous fluid, whilst the rest is a mixture of gases, but contains likewise no small portion of the volatile vapors of different compounds, which remain dissolved in the cooled gases, without being condensed into liquids. A coaly residue which is termed *coke* is left.

The researches of numerous chemists upon coal tar, have led to the discovery of oily volatile products of very different chemical character, and which are chiefly carbides of hydrogen, with a very large proportion of carbon. To this class belong *anilin*, *leucolin*, *pyrrol*, *rosolic*, *brunolic*, and *carbolic acids*, and *naphthalin*. Most of these contain ninety per cent. of carbon, naphthalin as much as ninety-four; and in burning they deposit it in still greater quantity than olefiant gas. It is, therefore, easily conceived why the vapors of these substances remaining with the gas, so very much enhance its value. Such mixtures of gas and vapor are termed illuminating gas, without reference to the separation of noxious and useless impurities before it is used. Gas, consequently, is not a definite compound of light carbide of hydrogen or olefiant gas, but more properly a mechanical mixture of very various bodies, some being only slightly or not at all luminous, whilst others are exceedingly so, as olefiant gas and the other carbides of hydrogen which possess similar properties, and to which the whole is indebted for its illuminating power. It is a remarkable circumstance, that carbon and hydrogen are capable of uniting in the same proportions by weight to form a series of gases and liquids, which only vary on account of the different amount of contraction of volume which their elements undergo in the moment of combination; and this alone can explain the great multiplicity of solid, liquid, and gaseous carbides of hydrogen which are known to exist.

It may be conceived that different substances, as wood, fat, and coal, must be suited in different degrees for the production of light-gas. Coal, fats, or oils, resin and tar, asphaltum, soap-water, and the refuse of animal bodies, are all practically employed, according to the locality, in the production of gas. The different nature of these bodies requires that different modes of preparing the gas from them should be adopted, and these will be considered separately further on.

The amount of gas from a given quantity of coal depends greatly upon its quality, and the manner in which its distillation is conducted; it is, therefore, very variable.

Experience has proved that English cannel is the best gas-coal, both as regards the quantity and quality of the gas which it yields. Scotch parrot coal comes next. Even the Berlin gas-works use cannel coal from England. In France, where cannel is not to be met with, highly caking coal of a similar character is selected, and on the East coast of England, caking coal is generally employed for the production of gas.

ACCUM found that one hundred cubic feet of coal gave from eighteen thousand seven huudred to nine thousand two hundred cubic feet of gas, according as the best kinds of Scotch or Lancashire coal were used, or the inferior sorts of Staffordshire. At the hospital at St. Louis, at Paris, the yearly average, from the same amount of coal, was twelve thousand three hundred cubic feet of gas, which is equal to four hundred and ninety-three cubic feet of gas to the hundredweight of coal. PRECHTL estimates the produce at seven hundred cubic feet; so that the statements as regards the weight of gas vary from twelve to seventeen per cent.

The decomposition of the coal begins with the incipient red heat of the enclosing vessels, and continues, if large quantities are employed, several hours, the quantity of gas gradually decreasing towards the end. PECKSTON found that, in an eight hours' distillation, when the fire was uniform, and the vessels constantly red hot, the relative quantities of gas given off were, in the first hour, twenty; in the second, fifteen; in the third, fourteen; in the fourth, nearly thirteen; in the fifth, twelve; in the sixth, ten; in the seventh, nine; and in the eighth, about eight per cent. of the whole quantity. The cubic foot at the end, therefore, costs two and a half times as much as at the commencement. The quality of the gas, at the different periods of the distillation, however, must also be taken into consideration. For this purpose, it will be proper to glance at the ingredients of the gaseous mixture in general, which, after the separation of the aqueous fluid and the tar, consists of—

Hydrogen,	H
Bihydride of carbon,	$C\ H_2$
Olefiant gas, $C_2\ H_2$, or	$C_4\ H_4$
Volatile hydrocarbon,	$C_8\ H_8$
Benzol,	$C_{12}\ H_6$
Carbonic oxide,	$C\ O$
Cyanogen,	$C_2\ N$
Sulphide of hydrogen,	$H\ S$
Ammonia,	$N\ H_3$
Carbonic acid,	$C\ O_2$
Sulphurous acid,	$S\ O_2$
Bisulphide of carbon,	$C\ S_2$
Nitrogen,	N

The carbonic oxide and a part of the free hydrogen, doubtless, have the same origin, being formed from the moisture in the coal, or from the first portions of aqueous vapor generated, which, passing over the incandescent coke, are converted into these gases. The nitrogen of the coal is obtained entirely as cyanogen and ammonia, partly in combination, and the latter is also found with the sulpho-cyanogen and the other acids, forming volatile salts; *free* nitrogen, on the contrary, is the residue of atmospheric air contained in the retort. Sulphide of hydrogen and sulphurous acid arise from iron pyrites, eviscerated by the coal.

The first four of the ingredients named, with the illuminating vapors of tar oil, form the proper bulk of the gas; the others are small quantities of impurities which should have been separated with the tar. Experiment has proved that the relative proportions of the four principal ingredients vary with the duration of the distillation. When chlorine is added to light-gas and the vapors of tar oil, a fluid compound separates, and the original volume is consequently lessened. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power and to the value of the gas —the amount of olefiant gas and tar oil vapors which it contains. This explains the following results of a series of elaborate experiments by Dr. HENRY, who followed analytically, step by step, the whole course of the evolution of gas. He found that, at incipient redness, scarcely anything but hydrogen, atmospheric air, and some tar passed off, with hardly any illuminating gas; but that, after attaining that temperature, illuminating gas alone appeared, and this was composed of a mixture of gases in the following relative proportions:—

Time of collection.	Specific gravity.	Out of a hundred parts of gas from Wigan cannel coal.				
		Chlorine absorbed	Carbide of hydrogen absorbed	Carbonic oxide absorbed	Hydrogen absorbed	Nitrogen absorbed
In the first hour,	0·650 0·620 0·630	13 12 12	82·5 72 58	3·2 1·9 12·3	0 8·8 16	1·3 5·3 1·7
Five hours after the commencement,	0·500	7	56	11	21·3	4·7
Ten do. do.	0·345	0	20	10	60	10

Consequently, as a general result, carbide of hydrogen is formed in decided excess, and the most luminous portion of this, which is condensable by chlorine, comprises only about one-fifth of the whole. These numbers also prove distinctly, that after about the fifth hour the quantity only increases, but the quality does not improve; indeed, this deteriorates so rapidly, that at the expiration of ten hours, the gas which passes over is hardly luminous when ignited, but burns with a very faint flame. The specific gravity, as will be seen, keeps pace with the quality of the gas, diminishing as the latter improves, and can thus far be taken as a test for its value. As pure olefiant gas has about the specific gravity of common air, 0·98, the density of the illuminating gas must increase with the quantity of olefiant gas contained in it; yet an extraordinary amount of carbonic oxide, specific gravity 0·97, or of carbonic acid, specific gravity 1·52, may give rise to errors of some magnitude.

The great increase of hydrogen, which at the last period amounts to sixty per cent., is remarkable, and important to the manufacturer—an augmentation which is no longer due to the decomposition of aqueous vapors, but to that of the carbides of hydrogen. It was long ago observed that these are decomposed at a bright red heat, and deposit a portion of their carbon on the sides of the vessels. MARCHAND's recent experiments show very clearly the progress of this decomposition. When olefiant gas was conducted through a red-hot tube, and the heat constantly elevated, the gas passing off, collected in successive portions, contained the following quantities of carbon to one hundred of hydrogen:—

Hydrogen.	Carbon.	Nature and temperature of the gas.
100	614	Olefiant gas.
100	580	Red heat.
100	533	—
100	472	—
100	367	—
100	325	Intense white heat.
100	307	Light carbide of hydrogen.
100	7	Continued white heat, nearly pure hydrogen.

The Editor will now give a short account of each gas, with its preparation and properties.

HYDROGEN.—First in the table of the constituents of coal-gas is this element, which in its pure state is a colorless transparent gas, possessing a very low specific gravity. It may be obtained by the action of weak sulphuric acid upon iron or zinc. Some nails, or pieces of iron wire, or granulated zinc, may be introduced into a tubulated flask, and covered with sulphuric acid, diluted with six or eight times its bulk of water; an effervescence ensues, heat is evolved, and the gas escapes, which may be collected in the hydro-pneumatic trough. The hydrogen, however, which is thus eliminated, is never perfectly pure. When procured from iron, its smell is peculiar and disagreeable, in consequence, according to BERZELIUS, of its containing a portion of volatile oil, formed by its union with a minute quantity of carbon, which all common iron contains. When such gas is passed through alcohol, much of the odor is absorbed by it, and on diluting it with water, it becomes milky. Obtained by means of zinc, the gas is perhaps somewhat more pure, but appears to hold a trace of zinc and of carbon in solution, and perhaps, in some cases, traces of sulphur and of arsenic. For the purposes of delicate experiments, hydrogen must be passed through a solution of potassa, and then exsiccated by conducting it over fragments of fused chloride of calcium; it should also be collected over mercury, and procured from *purified zinc*, and *pure* sulphuric acid, so far diluted as to act but slowly upon the metal.

Hydrogen is an uncondensable aeriform fluid; it is not absorbable by water, unless that liquid has previously been deprived, by long boiling, of common air, in which case a hundred cubic inches dissolve about 1·5 of the gas. It has no taste, and when perfectly pure is inodorous. It has great power of refracting light. It may be respired for a short time, though it is instantly fatal to small animals. M. MAUNOIR, after having breathed a quantity of this gas, found that his voice had become remarkably shrill. The intensity of sound is greatly diminished in an atmosphere of hydrogen; LESLIE, indeed, ascertained it to be more feeble than its rarity, compared with air, would have led him to expect. He placed a piece of clockwork, by which a bell was struck every half minute under the receiver of the air-pump, and after exhausting the air, filled the receiver with hydrogen; but the sound was then even feebler than in the highly rarefied atmosphere.

Hydrogen gas, says BRANDE, is the lightest known form of matter, and its equivalent, combining, or atomic weight, is below that of all other substances; it is, therefore, conveniently assumed as *unity* in reference to the *atomic weights* of all other bodies. In consequence of its extreme lightness, it is difficult directly to determine its weight with accuracy by the common process; but the researches of BERZELIUS and DULONG, and of Dr. PROUT, lead one to infer that its specific gravity, compared with oxygen, is as one to sixteen; one hundred cubic inches, therefore, of pure hydrogen gas at mean temperature and pressure, weigh only 2·1483 grains, and compared with air, its specific gravity would be nearly as seven to one hundred, or, more correctly, as 0·0694 to unity.

The low specific gravity of this gas is well and interestingly illustrated, by substituting it for common air in soap bubbles, which then rapidly ascend in the atmosphere, and may be kindled by the flame of a taper. The same circumstance also leads to its employment for the inflation of balloons, which, however, have of late years been generally filled with coal-gas. Small balloons may be purchased made of gold-beater's skin, or the lining membrane of the crop of a turkey, which, when filled with pure hydrogen, rise to the ceiling, their specific gravity being inferior to that of the surrounding air. Some of these, when filled with hydrogen, do not weigh more than forty-two grains, while the same bulk of air would weigh fifty-two, so that their buoyant power is about ten grains.

Hydrogen is inflammable, and extinguishes flame. When pure, it burns quietly, with a pale yellowish flame at the surface in contact with air.—*Brande.*

BIHYDRIDE OF CARBON—light carbide of hydrogen—is produced collaterally with carbonic acid, in the putrefaction of vegetal substances under water—hence its name, *marsh-gas.* It burns with a pale bluish light, rather stronger than hydrogen.

This gas is best obtained for experimental purposes by the decomposition of *certain acetates*, under the following conditions, first pointed out by PERSOZ, and described by DUMAS: forty parts of crystallized acetate of soda, forty of caustic potassa, and sixty of powdered quicklime, are well mixed and heated in a glass retort; the use of the lime being to prevent the action of the alkali upon the glass; at a heat approaching dull redness, the gas is abundantly evolved, and may be collected over water. The action is determined by the affinity of the alkaline bases for carbonic acid, and the instability of the acetic acid at high temperatures, an equivalent of acetic acid and one of water producing carbonic acid, which combines with the soda and potassa, while, at the same time, light carbide of hydrogen is formed, and passes off, as shown by the following formula:—

$$\underbrace{Na\,O,\ C_4\,H_3,\ O_3,}_{\text{Acetate of soda.}} + \underbrace{KO\,HO}_{\text{Potassa.}} = \underbrace{Na\,O\,CO_2}_{\text{Carbonate of soda.}} + \underbrace{KO\,CO_2}_{\text{Carbonate of potassa.}} + \underbrace{2\,(H_2\,C).}_{\text{Carbide of hydrogen}}$$

A mixture of one equivalent of fused hydrate of baryta, and one of anhydrous acetate of soda, similarly treated, also yield a pure gas.

Sir H. DAVY found the specific gravity of this gas to be 0·555, and, compared with hydrogen, as eight to one. One hundred cubic inches weigh 17·4 grains. According to FARADAY, its refractive power is 2·097, air being 1·000. When pure, it is of course unrespirable, but it is not very noxious when mixed with air. It is sparingly soluble in water, fourteen cubic inches of which take up about one of the gas. It is hardly sensibly soluble in alcohol or ether, and in oil of turpentine the proportion dissolved is not probably one-fifteenth of the volume of the fluid employed. It is inflammable, burning with a yellow flame, and producing carbonic acid and water; it has, when quite pure, scarcely any odor. It is not decomposed by electric sparks, but, when passed through a white-hot tube, deposits a portion of its carbon.

A hundred volumes of this gas require two hundred of oxygen for perfect combustion, which produces *water* and a hundred volumes of *carbonic acid.* One hundred volumes of carbonic acid contain a hundred of oxygen, or half the quantity consumed; the remaining hundred volumes, therefore, must have united with two hundred of hydrogen to form water; hence, this gas is composed of—

	Atomic weight.	Per cent.
1 Eq. of Carbon,	6	75
2 Eqs. of Hydrogen,	2	25
1 Eq. of Bicarbide of hydrogen,	8	100

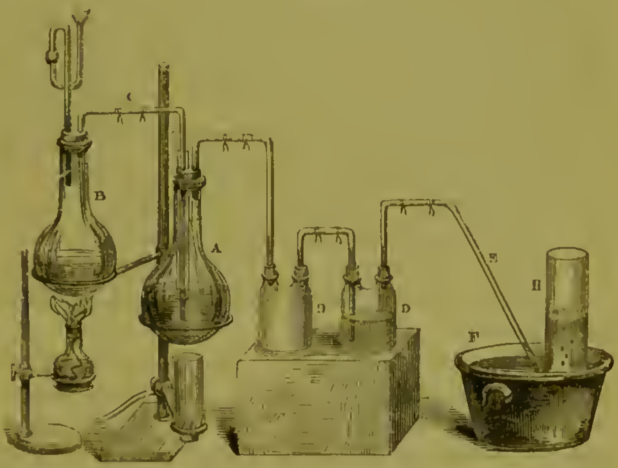
DAVY made several experiments on the combustibility and explosive nature of this gas. He observed that when one volume was mixed with one of air, they burned by the approach of a lighted taper, but did not explode; two of air and three of the latter to one of gas manifested similar results. When four of air and one of the gas were exposed to a lighted candle, the mixture being in the quantity of six to seven cubic inches in a narrow-necked bottle, a flame descended through the mixture, but no noise was produced; one volume of gas, burned with six of air in a similar bottle, made a slight whistling sound; one of gas with eight of air, rather a louder sound; one with ten, eleven, twelve, thirteen, and fourteen still inflamed, but the violence of the combustion decreased. A candle burned in a mixture of one of gas and fifteen of air, with a greatly enlarged flame, without producing explosion. The compound which appeared to be of the greatest explosive power, was that of seven or eight volumes of air to one of gas; but the report produced by fifty cubic inches of this mixture was less than that resulting from one-tenth of the quantity of a mixture of two parts of atmospheric air and one of hydrogen.

In reference to the *degree of heat* required to explode this gas mixed with its proper proportion of air, it was found that a common electrical spark would not explode five parts of air and one of the gas, though it exploded six parts of air and one of the gas; but very strong sparks from the discharge of a Leyden jar seemed to have the same power of exploding different mixtures of the gas as the flame of the taper. Well-burned charcoal, ignited to the strongest red heat, did not explode any mixture of air and of the fire-damp; and a fire made of well-burned charcoal, that is, charcoal that burned without flame, was blown up to whiteness, by an explosive mixture containing the fire-damp, without producing its inflammation. An iron rod at the highest degree of red heat, and at the common degree of white heat, did not inflame explosive mixtures of the gas; but when in brilliant combustion, it produced the effect. The flame of gaseous oxide of carbon, as well as that of olefiant gas, exploded the same mixtures.—*Brande.*

OLEFIANT GAS.—Next in order is the chief constituent of coal-gas—namely, olefiant gas, a name derived from its property of producing, when in contact with chlorine at the common temperature, a peculiar aromatic oil resembling chloroform.

This gas burns with a beautiful brilliant flame, constituting the true illuminating principle of coal-gas. It is generally obtained by decomposing alcohol by sulphuric acid; for which purpose, two parts by measure of the acid, and one of alcohol, are put into a retort, and heat applied; soon after the mixture boils, the gas is evolved. It may be collected over water, and should be well washed with lime water, or with a solution of potassa, to abstract sulphurous and carbonic acids; it also retains a little ethereal vapor, which may be removed by agitating it with weak alcohol, and afterwards with water. A more refined process for the production of olefiant gas is that of MITSCHERLICH, which consists in passing the vapor of alcohol into sulphuric acid, so far diluted as to have its boiling point reduced 325°—namely, about two parts vitriol, specific gravity 1·8, and one of water. The acid is heated to the boiling point, or nearly so, and is then put into the receiver, A, Fig. 89. The flask, or tubulated retort, B, contains alcohol. On the application of heat to the latter, its vapor passes, by means of the tube, C, into the hot acid, and is converted—catalytically—into olefiant gas and aqueous vapor, which, after passing through a Woulfe's apparatus, D D, escape by the tube, E, together with a little alcohol and ether, into the pneumatic trough, F. The gas continues its course upwards into its recipient, H, while the accompanying bodies just mentioned are condensed in the trough. By this process the acid is not discolored, and no sulphurous acid is formed.

Fig. 89.



The apparatus may be variously modified. Thus, when it is required that the whole of the alcoholic vapor should be transformed into the olefiant gas, the ebullition of the acid must be continued by means of a spirit or gas lamp placed under the receiver. When the acid is merely heated in the first place, decomposition proceeds only till the acid is cold. Still, for preparing *a small quantity* of gas, this condition is quite sufficient.

The specific gravity of olefiant gas, as usually prepared, is about 0·980, or, compared with hydrogen, as fourteen to one, and a hundred cubic inches weigh about thirty grains. According to THOMSON, its specific gravity is 0·9722—the same as that of nitrogen and carbonic oxide—and a hundred cubic inches at the temperature of 32° weigh 31·879 grains. Its refractive power is 1·818, air being one; and its specific heat, compared with that of air, is, according to DULONG, 1·53, and according to DE LA ROCHE and BERARD, 1·55, being greater than that of any other gas.

Under the combined influence of intense cold and pressure, FARADAY succeeded in condensing olefiant gas into a clear, colorless, transparent liquid, not solidifiable: its vapor exerts a pressure of 26·9 atmospheres at 0°.

Olefiant gas, when carefully purified, has little odor, though it is very difficult to get rid of traces of ether; it is inflammable, burning with a bright and highly luminous flame. It extinguishes a taper, and is quite irrespirable. Water absorbs about one-eighth its volume of olefiant gas, leaving an insoluble residue, which burns like light carbide of hydrogen.

MARCHAND states that one volume of olefiant gas requires, for perfect combustion, three of oxygen. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphide of hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that olefiant gas contains two volumes of hydrogen condensed into one; hence the quantity of oxygen required for its combustion. This compound is also decomposed by heat alone, as by passing and repassing it through a red-hot tube of earthenware or metal; it then gradually deposits its carbon, and is ultimately expanded into twice its original volume of pure hydrogen. An analogous transformation of the olefiant gas generated in the retorts of the gas-works is observed, and is connected with the deposition of several interesting forms of carbon.

When *one* volume of olefiant gas is detonated by the electric spark in a proper tube—which, on account of the violence of the explosion, should be very strong—with three volumes of oxygen, *two* of carbonic acid are formed, and water is deposited. Now two volumes of carbonic acid contain two of oxygen, so that the other volume of oxygen must have condensed two of hydrogen to form water. Hence *one* equivalent or volume of olefiant gas must contain *two* equivalents of carbon and *two* of hydrogen.—*Brande.*

VOLATILE HYDROCARBONS.—Next in order, among the constituents of coal-gas, are the volatile hydrocarbons, portions of which vaporize at a heat much below that of boiling water; consequently, parts of them are carried off by the coal-gas—the quantity found in the gas varying with the distance from the works in which it is generated.

BENZOL contains ninety-two per cent. of carbon, a far greater amount than even olefiant gas. When it is burned with an insufficient supply of oxygen, large deposits of carbon ensue. With a proper quantity of oxygen, this hydrocarbon affords a beautiful light, as may be observed when a stream of atmospheric air is transmitted through it during ignition. The peculiarly rich and illuminating power of the vapor of benzol, may be seen by passing it through the pale and almost invisible flame of hydrogen. This substance has been fully described in Vol. I., page 285, *et sequitur.*

CARBONIC OXIDE, which is rather an impurity than a proper constituent of coal-gas, may be very readily obtained, as BRANDE remarks, by DUMAS' process, which consists in gently heating oxalic acid with five or six times its weight of sulphuric acid; the mixture effervesces in consequence of the evolution of equal volumes of carbonic oxide and carbonic acid gas; the latter may be abstracted by a caustic alkaline solution, and pure carbonic oxide gas remains. In this case, the evolution of the two gases is caused by the abstraction of water from oxalic acid, which contains, in its anhydrous state, the elements of one equivalent of carbonic oxide, and one of carbonic acid; but these can only exist as oxalic acid when in union with water, or with a base, anhydrous oxalic acid not having been isolated. Crystallized oxalic acid is $C_2\,O_3$, 3 HO, which, acted upon by three equivalents of sulphuric acid, 3 (HO, $S\,O_3$), becomes 3 (2 HO, $S\,O_3$) + CO_2 + CO; the hydrated sulphuric acid remains in the retort, the carbonic acid is abstracted by passing the gases through a solution of caustic potassa, and the carbonic oxide passes off. Another source of carbonic oxide, suggested by FOWNES, is the action of ten parts of concentrated sulphuric acid on one part of pulverized crystals of ferrocyanide of potassium; the gas thus obtained is pure, and is evolved in the proportion of three hundred cubic inches from half an ounce of the salt.

Ferrocyanide of potassium contains cyanide of potassium, $K\,C_2\,N$, and cyanide of iron, $Fe\,C_2\,N$; they are converted by the sulphuric acid into sulphates of iron and potassa, sulphate of ammonia, and carbonic oxide; thus, in regard to the cyanide of potassium,

$$\underbrace{K\,C_2\,N}_{\text{Cyanide of potassium.}} + \underbrace{2\,(HO.\,SO_2)}_{\text{Sulphuric acid.}} + \underbrace{2\,HO}_{\text{Water}} = \underbrace{KO,\,SO_3}_{\text{Sulphate of potassa.}} + \underbrace{N\,H_4\,O.\,SO_3}_{\text{Sulphate of ammonia.}} + \underbrace{2\,CO.}_{\text{Carbonic oxide.}}$$

It not unfrequently happens that carbonic oxide is formed by the combustion of carbon when the supply of oxygen is inadequate to the production of carbonic acid; hence the lambent blue flame which sometimes plays upon a coke or charcoal fire, or is seen to issue from certain furnaces: this is, in fact, equivalent to passing carbonic acid over red-hot charcoal; so that $C\,O_2 + C$ becomes 2 C O.

The specific gravity of this gas compared to hydrogen is as fourteen to one; and to atmospheric air as 0·9706 to 1·0000; a hundred cubic inches weighing 29·0979 grains. It is very fatal to animals, causing giddiness and fainting when respired mixed with atmospheric air. When breathed pure, it almost immediately produces profound coma. It extinguishes flame, and burns with a peculiar blue light when mixed with, or exposed to, atmospheric air. DAVY found that the temperature of an iron wire heated to dull redness was sufficient to inflame it. It has no taste and little odor; it does not affect vegetal colors, occasions no precipitate in lime water, and is very sparingly absorbed by water which has been deprived of air. When burned in dry air or oxygen under a bell-glass, no moisture whatever is deposited, showing that hydrogen is not contained in this gas. Carbonic acid is the only result of this combustion.—*Brande.*

No change is effected in carbonic oxide when it is passed and repassed through a red-hot porcelain tube; nor is it altered at high temperatures by phosphorus, sulphur, nor even, according to the experiments of SAUSSURE, by hydrogen, though it is stated upon other authorities, that at elevated temperatures hydrogen does decompose it.

CYANOGEN.—There is no class of organic bodies, remarks Sir ROBERT KANE, of which there is more extensive and exact knowledge, than those which have cyanogen as their basis. The powerful affinities which this radical exerts, the simplicity of its constitution, and above all, the circumstance that one is able to prepare it in an isolated state, and to generate its compounds directly from it, as from those of a truly simple body, renders its history the most advanced portion of organic chemistry, and that to which the analogy of mineral bodies, and the theory of compound organic radicals, is most undeniably applicable.

Cyanogen does not exist in nature ready formed; the kernels of peaches, plums, bitter almonds, *et cetera*, and the leaves of the cherry-laurel, yield, by distillation, abundance of hydrocyanic acid, but it is only then produced by the decomposition of other substances containing nitrogen.

This body may, however, be formed abundantly, and in a simple manner, by bringing its elements together at a high temperature, in contact with substances with which it may unite. Thus, when any organic matter containing nitrogen is calcined with potassa, the nascent carbon and hydrogen unite, and cyanide of potassium is produced; even with pure charcoal this occurs, nitrogen being derived from the air; and FOWNES has shown, that when a mixture of pure charcoal and potassa is ignited in a tube, and a current of nitrogen passed through it, the latter is absorbed, and carbonic acid gas being given off, cyanide of potassium is produced—

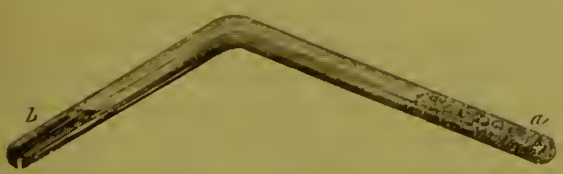
$$3\,C + KO + N = CO + K, C_2\,N.$$

This mode of forming cyanogen has been made the basis of manufacturing processes on the great scale, and at present much ferrocyanide of potassium so formed is sent into commerce. By the action of ammonia also on ignited charcoal, cyanogen is generated in abundance; it combines with hydrogen and the excess of ammonia, and produces ferrocyanide of ammonium. It is by virtue of these processes, that cyanogen is obtained for its various applications in the arts.

Cyanide of silver, or cyanide of mercury, is to be introduced into a small glass retort, and heated to just below redness; a gas is evolved which must be collected over the mercurial trough; the cyanide of silver separates simply into metal and cyanogen; but when cyanide of mercury is used, a brown powder appears, the quantity of which is less as the temperature of its decomposition has been lower. The gas which comes over is, however, cyanogen absolutely pure. If a large supply of this gas be required, but not of absolute purity, it may be prepared by mixing boiling solutions of two parts of chloride of mercury, and three parts of ferrocyanide of potassium, and evaporating down the liquor; the dry mass, which is a mixture of cyanide of mercury, chloride of potassium, and cyanide of iron, gives out on the application of heat a very large quantity of cyanogen, nearly pure.

The properties of this gas are very distinct. It is colorless, has a sharp smell, which irritates tho eyes. Its specific gravity is 1·819. If a quantity of cyanide of silver be sealed up in a strong tube, bent as in Fig. 90, and then heated at one end, *a*, the cyanogen is evolved and condensed by a pressure of about four atmospheres, and collects at the other end, *b*, as a colorless liquid. It is combustible, burning with a beautiful rose-colored flame, and producing two volumes of carbonic acid and one of nitrogen. It is constituted, therefore, of equal volumes of carbon vapor and nitrogen, the two volumes being condensed to one; hence, 0·836 + 0·976 = 1·812, is its specific gravity. It dissolves abundantly in alcohol and water, but these solutions soon undergo very complex decompositions; the liquor being found to contain carbonic acid, hydrocyanic acid, ammonia, urea, and oxalic acid, besides a brown insoluble matter. A similar decomposition is produced much more rapidly by contact with aqueous ammonia. The composition of this brown matter appears to be $C_4\,N_2\,HO$. It dissolves in alkalies, and gives precipitates with the metallic salts; it has been hence termed *azulmic acid*. When heated it gives off cyanogen, which has been termed *paracyanogen*. This may be also formed by heating cyanide of mercury very strongly. It dissolves in hot nitric acid, and the solution gives, with water, a yellow precipitate, which combines with bases.

Fig. 90.



Cyanogen unites directly with hydrogen and with the metals, but its oxygen combinations require to be indirectly formed; there are three compounds of cyanogen and oxygen, which are all acids, and are polymeric bodies. It combines also with sulphur, and its compounds with this element have a remarkable tendency to form double and triple combinations.

The formula of cyanogen is indifferently written $C_2\,N$ or Cy. Its equivalent number is 26.—*Kane.*

SULPHIDE OF HYDROGEN is best prepared by acting upon the sulphide of iron with dilute sulphuric acid. A lively effervescence ensues from the escape of this gas, and the solution contains protosulphate of iron; a gentle heat may be applied to facilitate the decomposition. In this process water is decomposed, its oxygen uniting with the iron, and its hydrogen with the sulphur; the change may be represented by the following—

$$\underbrace{Fe\,S}_{\text{Sulphide of iron.}} + \underbrace{HO\,S\,O_3}_{\text{Sulphuric acid.}} = \underbrace{H\,S}_{\text{Sulphide of hydrogen.}} + \underbrace{Fe\,O\,S\,O_3.}_{\text{Sulphate of iron.}}$$

This gas may also be obtained by acting on sulphide of potassium by dilute sulphuric or hydrochloric acid, in which case the result is similar to that already given. Sulphide of antimony and hydrochloric acid produce, when heated, very pure sulphide of hydrogen, the reaction being—

$$\underbrace{Sb_2\,S_3}_{\text{Tersulphide of antimony.}} + \underbrace{3\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Sb_2\,Cl_3}_{\text{Terchloride of antimony.}} + \underbrace{3\,HS.}_{\text{Sulphide of hydrogen.}}$$

As sulphide of hydrogen is absorbed by water, it cannot well be collected over this liquid, except it be saturated with chloride of sodium, or be heated to above 90°, in which case its solvent power is very much diminished. It cannot be kept long over the mercurial trough, for the lead and tin, always present in the mercury of commerce, gradually decompose it, combining with the sulphur, and leaving the hydrogen free; the volume of the gas remains the same during this chemical reaction.

This gas is colorless and transparent; it is characterized by the fetid odor of rotten eggs, which, in fact, owe their peculiar smell to the production of this gas during their putrefaction. Its specific gravity is 1·177.

Sulphide of hydrogen gas dissolves in water, forming a solution used extensively as a reagent for most of the metals, from the solutions of which it precipitates metallic sulphides of various colors, by which many metals are distinguished.

When aqueous sulphide of hydrogen is exposed to the air, oxygen is absorbed, which combines with the hydrogen of the sulphur compound, water being produced, while the sulphur is set free, and appears as a milky precipitate. The nascent sulphur, however, in part absorbs also oxygen, and sulphuric acid is formed; hence the presence of this acid, free, in volcanic springs, as in the Rio Vinaigre in New Spain. If a solution of sulphurous acid be mixed with sulphide of hydrogen, half of the whole quantity of sulphur is precipitated, and the remainder is converted into pentathionic acid—

$$\underbrace{5\,S\,O_2}_{\text{Sulphurous acid.}} + \underbrace{5\,H\,S}_{\text{Sulphide of hydrogen}} = \underbrace{5\,S}_{\text{Sulphur.}} + \underbrace{5\,HO}_{\text{Water.}} + \underbrace{5\,(S\,O).}_{\text{Pentathionic acid.}}$$

Sulphide of hydrogen is highly inflammable; if burned in a limited quantity of air, the hydrogen is consumed, whilst most of the sulphur is deposited. By means of chlorine or nitric acid, it may be completely decomposed; hence, chlorine acts as a disinfectant and purifier of sewers or rooms impregnated with the odor of sulphide of hydrogen. The annexed represents the decomposition:—

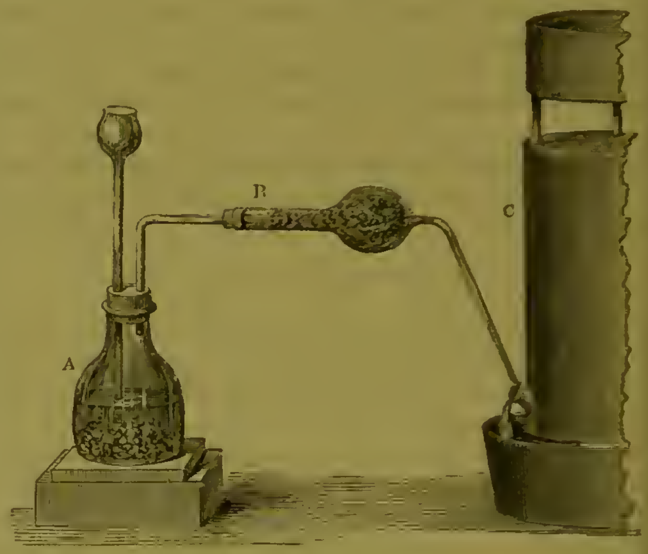
$$\underbrace{H\,S}_{\text{Sulphide of hydrogen.}} + \underbrace{Cl}_{\text{Chlorine.}} = \underbrace{H\,Cl}_{\text{Hydrochloric acid.}} + \underbrace{S}_{\text{Sulphur.}}$$

This gas is very poisonous; air containing only one eight-hundredth part producing death. Many of the metals decompose sulphide of hydrogen, particularly when heated in this compound, combining with the sulphur, and setting free the hydrogen. This occurs slowly, even at common temperatures; hence metals, as gold and silver, which are not oxidized by the air, are gradually tarnished by sulphide of hydrogen, which, exhaled from decomposing animal matter, is always present in the atmosphere. This gas, evolved probably by the action of water on the native sulphides of iron, at high temperatures, is a frequent constituent of mineral springs, and forms the class of spas termed sulphurous, such as those of Harrowgate, Lucan, and Golden-bridge. They are easily recognised by the fetid odor, by blackening a silver spoon, or by giving a black or brown precipitate with a solution of a lead salt.—*Kane.*

AMMONIA.—A full description of this volatile alkali is given in Vol. I., page 177, *et sequitur.*

CARBONIC ACID exists in the atmosphere as a product of combustion, and of the respiration of animals. Combined with metallic oxides, it forms the numerous class of native earthy and metallic carbonates, of which the carbonate of lime is much the most important. It is a result, also, of the slow decomposition of vegetal substances, and is evolved in great quantity from the ground in volcanic countries. In the fermentation of sugar, it is produced in abundance along with alcohol. For the purposes of the chemist, it is generally prepared by decomposing marble, or calc-spar, by means of any strong acid; from its cheapness, and the solubility of the residual salt, hydrochloric acid is generally employed. Some fragments of carbonate of lime being placed in a wide-necked bottle, A—Fig. 91—the acid diluted with its own volume of water, is poured in by means of a funnel, as represented in the figure, and the gas which is evolved is conducted through the tube, B, filled with fragments of recently fused chloride of calcium to remove any moisture. It then passes into the gasometer, C, to be made use of as required. The decomposition is as follows:—

Fig. 91.



$$\underbrace{Ca\,O\,CO_2}_{\text{Carbonate of lime}} + \underbrace{H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Ca\,Cl}_{\text{Chloride of calcium.}} + \underbrace{HO}_{\text{Water.}} + \underbrace{CO_2}_{\text{Carbonic acid.}}$$

The gas, owing to its gravity, may be received in a wide-mouthed bottle. which in this case is ascertained to be full by applying a lighted taper to the mouth, when it is immediately extinguished.

The properties of this gas are exceedingly striking; it is entirely void of color, and invisible; it is irrespirable, producing, when an attempt is made to breathe it, violent spasms of the glottis. If it be inhaled with air, even in the proportion of one to ten, it gradually produces stupor and death, acting as a narcotic poison. Its specific gravity is 1·511; hence, when disengaged in large quantity, whether by natural operations, or in the process of manufacture, it accumulates in all cavities within its reach, and may cause fatal accidents to animals which enter inadvertently. Workmen engaged in cleaning out dry wells or vaults, or the large vats from which fermenting liquors have been run off, should carefully observe whether a candle can remain for some time burning brightly at the bottom. In volcanic countries, chasms are frequently occupied to the level of their surface by this gas, exhaled from the ground; and an experiment often shown, to amuse the traveller, consists in walking into such a cavern with a dog, which, holding the head near the floor, is almost instantly asphixated by the inferior layer of carbonic acid, whilst men, whose heads are above the level, breathe pure air; the dog, on being thrown into a neighboring pond, recovers from the stupor. Carbonic acid does not support combustion, a burning taper held in a jar of it being instantly extinguished; and the high specific gravity of the gas may be easily illustrated by placing a lighted taper at the bottom of a vessel holding air, and taking in the hand another containing carbonic acid; on inclining the latter, the heavy gas can be poured into that which contains the lighted taper—just as water may be emptied from one vessel to another—and falling to the bottom, extinguishes it.

Water absorbs its own volume of carbonic acid gas, forming a solution possessing an agreeably acid taste, and which sparkles when agitated. It changes blue litmus into a wine-red, which, by exposure to the air or heat, disappears. By means of pressure, water can be made to retain a large quantity of this gas, which escapes with effervescence when the pressure is removed, and is thus the basis of a variety of ogreeable effervescing beverages. Carbonic acid dissolved in water precipitates solutions of lime and baryta white, forming carbonates, which redissolve in an excess of this acid.

Under a pressure of thirty-six atmospheres, carbonic acid may be liquefied. It then forms a colorless, exceedingly mobile liquid, having a specific gravity 0·83 at 32°, which is remarkable for its excessive expansibility by heat—this being four times that of air, or nearly one per cent. for each degree of Fahrenheit. When the pressure is suddenly removed from the liquid acid, it regains the elastic form with such rapidity, that, in consequence of the amount of latent heat with which the vapor combines, and which is abstracted from the liquid portion, part of it is frozen to a solid. Solid carbonic acid can thus be obtained in large quantity by an apparatus contrived by THILORIER. It is a white body in filamentous masses, like asbestos; it evaporates but slowly; it is very soluble in alcohol and ether; the latter solution produces by its evaporation the most intense cold known, estimated at *minus* 166°.—*Kane.*

SULPHUROUS ACID exists at ordinary temperatures and pressures in the gaseous form, but is one of the most easily condensable gases. It is always produced when sulphur is burnt in the atmosphere, or in pure oxygen, sulphur being incapable of passing directly into a higher degree of oxidation. In the burning of sulphur, the volume of sulphurous acid gas produced equals exactly that of the oxygen consumed.

When desired pure, it is usually prepared by decomposing sulphuric acid, by means of a metal not very easily oxidized, as mercury or copper. The metal combines with one equivalent of the oxygen of the sulphuric acid, and the sulphur with the remaining two equivalents of oxygen pass off as sulphurous acid gas; the oxide obtained unites with the sulphuric acid to form a salt. Thus, taking mercury for an instance:—

$$\underbrace{\mathrm{Hg}}_{\text{Mercury.}} + \underbrace{2\,\mathrm{S\,O_3}}_{\text{Sulphuric acid.}} = \underbrace{\mathrm{S\,O_2}}_{\text{Sulphurous acid.}} + \underbrace{\mathrm{Hg\,O\,S\,O_3}}_{\text{Sulphate of mercury.}}.$$

If the temperature be not elevated beyond 200° in this process, it is black or suboxide of mercury which is produced—$Hg_2\,O$—but above that degree the red oxide—Hg O—alone is formed.

Sulphurous acid gas is absorbed by water; and hence, in order to examine its properties in that state, it must be collected over mercury. It is colorless and transparent, having a peculiar irritating odor, and cannot be respired. It is neither combustible, nor a supporter of combustion. It possesses bleaching properties, owing to which it is used in the arts to whiten straw bonnets, corn, silk, sponges, and other substances; if a red rose be exposed to the flame of burning sulphur, it becomes completely white.

When this gas is exposed to a temperature at zero, it condenses into a liquid, which boils at 14°, and produces by its evaporation intense cold.

Water dissolves about thirty-seven times its volume of this gas; the solution possesses the properties of sulphurous acid in a very high degree, and bleaches vegetal colors with great power; when kept for some time it gradually absorbs oxygen, and the sulphurous becomes converted into sulphuric acid.

Sulphurous acid is one of the most feeble acids known, and is expelled from its combinations by almost all acids but carbonic, to which the Editor has shown that it bears a most striking resemblance, and this even extends to the salts of both.

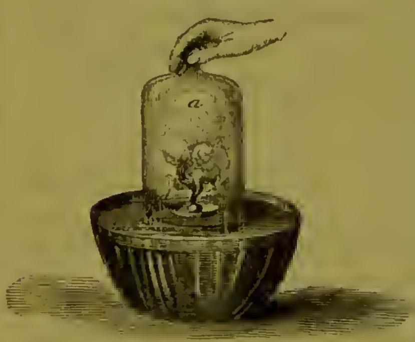
BISULPHIDE OF CARBON.—This remarkable substance is obtained whenever sulphur comes in contact with red-hot charcoal. Procured in this way, it contains an excess of sulphur dissolved in it, and must be purified by redistillation at a very moderate heat; when about nine-tenths have distilled over, by allowing the residue to evaporate spontaneously in a capsule, very fine right rhombic crystals of sulphur deposit.

The bisulphide of carbon is a colorless liquid possessing a very disagreeable alliaceous odor. It does not mix with water, but dissolves in alcohol and ether. Sulphur and phosphorus are soluble in it in large quantity. Its specific gravity is 1·272. It boils at 108°, and forms a colorless vapor, the specific gravity of which is 2·621. From its volatility, it obtained the name of *alcohol of sulphur.* While evaporating, it produces great cold; mercury may be frozen by suspending under the bell-glass a thermometer, the bulb of which is surrounded by cotton moistened with this fluid, and rapidly exhausting the air. It is very inflammable, burning with a blue flame, and producing carbonic and sulphurous acids. If a few drops of it be allowed to fall into a strong bottle containing oxygen, it detonates when touched with a lighted taper, like a mixture of oxygen and hydrogen. When the bisulphide of carbon is heated in contact with a metal, carbon is separated, and a metallic sulphide produced, which proves it to consist of one equivalent of carbon united with two of sulphur.

It is a powerful sulphur-acid, combining with the sulphides of the alkaline metals, and yielding sulphur-salts, which are crystallizable; with the sulphides of lead, silver, copper, *et cetera*, it forms insoluble compounds, which correspond closely in composition to the ordinary carbonates. This substance, in fact, exactly corresponds to carbonic acid—$C\ O_2$—the sulphur being replaced by oxygen, and hence it is often called sulpho-carbonic acid.—*Kane.*

NITROGEN is one of the two gases that constitute the atmosphere; it serves only to modify the effect of oxygen, and render the air fit and suitable for respiration: it is called nitrogen, from being the basis of nitric acid. It is also called by some chemists *azote*, from its incapability of supporting existence; but the former name is generally used, as a great many other gases have not the power of sustaining life.

Fig. 92.



Nitrogen exists in great quantity in the atmosphere; it is readily procured by abstracting the oxygen from a confined portion of the air, when nitrogen remains almost entirely pure. Thus, if a small piece of phosphorus laid in a cup, *d*, floating in water, be set on fire, and a bell-glass, *a*, be inverted over it, the phosphorus, in burning, unites with the oxygen of the air, and forms white fumes of phosphoric acid. At first, from the great expansion of the air, caused by the high temperature of the flame, some bubbles escape from under the edge of the glass, but soon, even before the phosphorus ceases to burn, the water begins to rise in the bell, and finally, the clouds of phosphoric acid gradually dissolving in the water, the residual gas will be found to occupy four-fifths of the original volume of the air, and to be colorless. Any combustible body would answer the same purpose, although not so perfectly as the phosphorus.

Independent of this source of nitrogen in atmospheric air, it may be obtained indirectly from other substances. Thus, most animal matters contain nitrogen in large quantity, united to carbon, hydrogen, and oxygen. If, therefore, some pieces of muscle, or albumen, or gelatin, be boiled in a retort with nitric acid, the oxygen of the latter combines with the carbon and hydrogen of the animal substance, forming different compounds, according to the temperature and the proportions, whilst the nitrogen of both is disengaged.

Nitrogen is a permanent gas, colorless, and transparent; it is absorbed by water only in very small quantity. It is lighter than atmospheric air, its specific gravity being 0·976, air being 1·000. It is characterized by the complete absence of the positive properties which distinguish other gases. Thus it does not support combustion or respiration; it extinguishes a taper, and animals are suffocated in it; but these effects appear to be due only to the absence of oxygen.—*Kane.*

AQUEOUS VAPOR.—It will be necessary merely to allude to the aqueous product of the distillation of coal, which is water holding in solution—

Carbonate of ammonia.
Sulphate of ammonia.
Sulphide of ammonium.
Chloride of ammonium.
Ferrocyanide of ammonium.

Most of these are fully described in Vol. I., page 183, *et sequitur*, and therefore, being only secondary products, need not be further dwelt upon.

OILY MATTERS.—The oily portion consists of—

Liquid.	Benzol,	Neutral,	$C_{12}\ H_6$	Constituents of naphtha.
	Toluol,		$C_{14}\ H_8$	
	Cumol,		$C_{18}\ H_{12}$	
Liquid.	Anilin,		$C_{12}\ H_7\ N$	Constituents of heavy oil of tar.
	Picolin,		$C_{12}\ H_7\ N$	
	Leucolin,		$C_{18}\ H_8\ N$	
	Hydrate of Phenyl—acid—		$C_{12}\ H_6\ O_2$	
Solid.	Naphthalin,		$C_{20}\ H_8$	
	Paranaphthalin,		$C_{30}\ H_{12}$	
	Pyren,		$C_{30}\ H_{12}$	
	Chrysen,		$C_{42}\ H_{14}$	

The Editor having learnt that the little information with reference to these ingredients, which is given in the treatises on gas hitherto published, has been felt as a want, will now refer to them individually; because, although secondary in point of importance, they are highly interesting, as being so intimately connected with the manufacture of coal-gas, which will constitute the principal subject of this article:—

Toluol.—When tolu balsam is distilled, there passes over a large quantity of benzoic, mixed with a little cinnamic acid, and a yellow liquid, which is a mixture of *toluol* and benzoic ether. By redistilling this, so as only to collect the portions which pass over between 265° and 285°, a distillate is obtained, which, when deprived of benzoic acid by distillation with solid caustic potassa, possesses the properties which belong to toluol.

It is a colorless limpid liquid, having an odor like benzol, volatile without residue, and boils at 226°; the density of its vapor is 3·246. When it is acted on by concentrated nitric acid, and water afterwards added, an oily fluid is obtained, which is nitrotoluid, $C_{14}\ H_7\ NO_4$, or, according to the Editor, toluol in which one equivalent of hydrogen is replaced by peroxide of nitrogen. By the action of sulphide of ammonium upon nitrotoluid, a yellow oil, which gradually solidifies into a crystalline mass, is obtained. To this substance, which acts as an *organic base*, the Editor gave the name of toluidin.

It crystallizes from its hot alcoholic solution in large broad plates. It is soluble in pyroxylic spirit, sulphide of carbon, and the fat and volatile oils, with the same facility as in spirit of wine; it is very sparingly soluble in water; it has a vinous aromatic smell and burning taste; it has no action upon turmeric, but it changes red dahlia paper to green. With nitric acid it produces a fine scarlet color, whereas anilin, so treated, assumes a blue tinge. The extraordinary crystalline tendency which distinguishes the salt of anilin, belongs also to toluidin; its alcoholic solution almost immediately solidifies when mixed with an acid. Its salts are inodorous, and, with the exception of the platinum and palladium compounds, colorless. It gave on analysis the following:—

		Theory.	Editor.
14 Eqs. of carbon, ...	84	78·50	78·53
9 Eqs. of hydrogen, ...	9	8·41	8·61
1 Eq. of nitrogen, ...	14	13·09	12·86
1 Eq. of toluidin, ...	107	100·00	100·00

Cumol occurs with hydrocyamid in Roman cumin oil, which, when distilled in an oil-bath, parts with a volatile acid, the hydrocyamid, at 165°, and in the residue the cumin oil remains as a colorless liquid, retaining a strong odor of Roman cumin oil, and a sharp burning taste; boils at 220°. By the action of cyanide of potassium, cumin oil is converted into a product resembling benzoin; in the air, and by the influence of oxidation, it yields cuminic acid. If cumin oil be boiled a long time with nitric acid, there is obtained nitrocuminic acid.

Anilin.—This base, which has the same constitution as picolin, exists in coal-tar oil, as well as in DIPPEL's oil; that which, by fractional distillation of the mixed bases, passes over at 182° is anilin. If sulphide of hydrogen be transmitted into an alcoholic solution of nitrobenzid, saturated with ammonia, sulphur is separated, and shortly the whole stiffens at 0° to a mass consisting of yellow crystalline needles; if this be heated to 212°, the solution filtered away from sulphur, and the filtrate distilled until the contents of the retort separate into layers, then is the lower one *anilin*, which is purified by distillation. It is a colorless fluid, strongly refracts light, has a penetrating odor, taste sharply burning, specific gravity 1·020, boiling point 182°; easily soluble in cold water, alcohol, and ether; if the aqueous solution be warmed it clouds, a portion of anilin being separated; it does not possess an alkaline reaction, but coagulates albumen; in contact with hydrochloric acid it forms a white vapor. When anilin is exposed to air it absorbs oxygen, and becomes yellow, brown, and resinous. A few drops of fuming nitric acid added to anhydrous anilin produce a fine blue color, which on slightly heating the mixture becomes yellow, and violent action ensues, sometimes followed by explosion; otherwise, the liquor passes through various hues, and crystals of nitropicric acid are ultimately formed. When anilin is added to a solution of hypermanganate of potassa, binoxide of manganese, oxalic acid, and ammonia are formed.

If to a solution of chloroxide of calcium—bleaching powder—anilin be added, a deep violet color is obtained, which in the presence of acids becomes red. By these reactions, anilin is distinguished from the other bases which have the same constitution. With the acids, anilin forms crystallizable inodorous salts, which are soluble in water and in alcohol, and which in the moist air soon become rosy-red. Anilin precipitates the salts of the protoxide and sesquioxide of iron, alumina, and oxide of zinc. Cyanide, ferrocyanide, and sulphocyanide of potassium, do not react upon salts of anilin; tannin causes a brown precipitate.

Picolin occurs in DIPPEL's oil, as also in coal-tar, and in each part thereof, which, on distillation, goes over first, together with anilin. It is more volatile than anilin, and can, therefore, be separated by fractional distillation; what passes over at 133° is pure picolin. It is a flowing liquid of a strong, penetrating, somewhat aromatic smell, and sharp, burning, bitter taste; still fluid at 17°, boils at 133°, specific gravity 0·955; mixes with water, alcohol, and ether in all proportions; it is not precipitated by a solution of bleaching powder, does not coagulate albumen, reacts alkaline. Nitrate of silver, chlorides of barium and strontium, and sulphate of magnesia, are not apparently affected by picolin; tannin causes a white caseous precipitate. It combines with the chlorides of mercury, platinum, tin, and antimony. If picolin be added to a solution of chloride of gold, fine lemon crystals are obtained. The salts possess the property of crystallizing.

Leucolin or *Quinolin.*—This base is found in the least volatile portion of the basic oil of coal-tar, and is also formed when quinin, cinchonin, strychnin, and thialdin, are heated with potassa. It has a disagreeable odor, and boils at 460°; its specific gravity is 1·081. It neutralizes acids, forming difficultly crystallizable salts. Its refractive and dispersive power is as high as that of bisulphide of carbon.

Hydrate of Phenyl, or *Carbolic acid.*—LAURENT obtained from that portion of the oil of tar which boils between 300° and 400°, *carbolic acid*, a compound which it has been found convenient to represent as the hydrated oxide of a radical which has been termed *phenyl.* It is obtained by agitating the oil with about twice its volume of *aqua potassæ*, pouring off the watery portion, and saturating it by hydrochloric acid. The carbolic acid separates in the form of a heavy oil, which may be purified by continuous distillation over a small quantity of caustic potassa.

Hydrate of phenyl is a colorless oily liquid, neutral to litmus paper, of a high refractive power, specific gravity 1·062. It has a penetrating odor, a pungent burning taste, and acts powerfully on the skin; it occasionally assumes the form of acicular crystals, which fuse at 94° and boil at 368°. It is slightly soluble in water. It forms crystallizable salts with the alkalies, which, however, retain an alkaline reaction; in many of its properties it resembles creasote. It unites with sulphuric acid to form sulphocarbolic or sulphophenic acid; with chlorine, bromine, and nitric acid, it yields various compounds.

Naphthalin is readily procured by the distillation of coal-tar, but its quantity is considerably enlarged if chlorine be transmitted into the menstruum, or if the latter be treated with bleaching powder, water, and sulphuric acid. Naphthalin always passes over last in the distillation of tar, mixed, however, with paranaphthalin, from which it is separated by treatment with alcohol, in which menstruum the latter is insoluble;

both bodies are deposited if the distillate be cooled to 10°. Naphthalin is purified by recrystallization from the hot alcoholic solution; it crystallizes by slow evaporation in thin, white, rhombic leaflets, and by slow sublimation in white, extremely light flakes of peculiar odor, and burning aromatic taste; insoluble in water, readily soluble in alcohol, ether, acetic acid, and a solution of oxalic acid; melts at 79°, boils at 212°; specific gravity 1·045. Easily distils with vapor of water; is inflamed with difficulty, and burns with a sooty flame.

Paranaphthalin or *Anthracin*, which is found in coal-tar, is obtained by the method given in connection with naphthalin. It is procured pure by repeated distillation. Its properties are similar to those of naphthalin, but it does not fuse below 300°; completely sublimable; insoluble in water, scarcely soluble in alcohol or ether, but easily in oil of turpentine. If anthracin is boiled for a few minutes with nitric acid, it is converted into a yellow mass accompanied by evolution of nitrous acid; the mass stiffens after cooling, and if it be then washed with water and treated with ether, a substance remains which has not been thoroughly investigated. This body melts at a high temperature, and by cooling congeals to a mass consisting of long needles.

Pyren is isomeric with anthracin, and is found in tar from wood, coal, and oil. If the last be distilled until one-fourth remains, and the residue again submitted to distillation in a small retort until there is only carbon left, a reddish substance is obtained, which consists of pyren, chrysen, and empyreumatic oils; if this mixture be treated with ether, the chrysen remains, and if the ethereal extract be slowly evaporated, the pyren is then precipitated. It crystallizes from the boiling alcoholic solution in clear rhombohedral prisms; melts at 170° to 180°, and stiffens crystalline; inodorous, tasteless; insoluble in water, little soluble in ether and alcohol; on the contrary, readily soluble in oil of turpentine. Boiled with nitric acid it gives a combination, which consists of $C_{30}\left\{\begin{matrix} H_{10} \\ 2\ NO_4, \end{matrix}\right.$ *id est*, pyren, in which two equivalents of hydrogen are replaced by two of peroxide of nitrogen.

Chrysen.—The production of this body is stated in connection with the preceding; it appears as an inodorous and tasteless powder; insoluble in water and alcohol, and scarcely soluble in ether and oil of turpentine; fuses at 230° to 235°; solidifies crystalline. If it be boiled with nitric acid, it is completely dissolved, and a compound results, the composition of which is doubtful, but the Editor is of opinion that it must have the formula $C_{42}\left\{\begin{matrix} H_{12} \\ 2\ NO_4. \end{matrix}\right.$

Besides these, there are various undescribed oils. Of these products, which are all contained in tar, it will be perceived that there is only oxygen in one, and this possesses acid properties. The first three are neutral, and constitute rectified coal naphtha. Three are alkaline, and contain nitrogen. The other four are solid and neutral. It is remarkable how few of the products of distillation have any oxygen, and how much they differ in this respect from those of wood; and that, where the oxygen does enter into combination, it produces compounds having no illuminating properties, namely, carbonic oxide, carbonic acid, and water; and that, in one instance, it unites with a compound of carbon and hydrogen, producing an acid oil that is found in very small quantity in the tar.

The nitrogen of the coal forms ammonia, cyanogen, and a few alkaline oils; the latter is discovered in minute quantity in the tar. The products are nearly all compounds of carbon and hydrogen; and respecting these it is further to be observed, that when the hydrogen exists in greater quantity than the carbon, as in carbide of hydrogen, which contains two equivalents of hydrogen to one of carbon, the compound is permanently gaseous; this gas has been subjected to a pressure of thirty-two atmospheres, and to cold 166° below zero, without liquefying. Olefiant gas, in which carbon and hydrogen exist in equal proportions, but in which two volumes of hydrogen and two of carbon are condensed into one volume, is durably gaseous; $C_{16}\ H_{12}$ is liquid; whilst naphthalin, $C_{20}\ H_8$; paranaphthalin, $C_{30}\ H_{12}$; pyren, $C_{15}\ H_3$; chrysen, $C_{12}\ H_4$, are solid. It may be safely asserted, that where the carbon and hydrogen exist in an equal number of equivalents, the compound will be gaseous, unless a very large number enters into the combination.

CHOICE OF GAS COAL.—What, then, are the practical inferences to be drawn from these statements? In the first place, it will be manifest that the greater the quantity of hydrogen, and the less oxygen and sulphur a cannel or coal may contain, the better it will be for gas-making; for the latter two rob the coal of a portion of its hydrogen, which is thereby prevented from uniting with a portion of carbon for the production of an illuminating gas. The coal should be selected as free from iron pyrites and sulphate of lime as possible, and lumps or masses of these should be thrown out, as they often occur in such a form in the coal.

EFFECTS OF WATER.—The coal should be moderately dried before being used, which can only be secured by its being stacked under cover, otherwise the rain would keep it saturated with moisture. The water, in its decomposition in the retorts, furnishes oxygen to the carbon of the coal, impoverishing the gas, whilst the hydrogen of the water does not combine with the carbon of the coal, but is liberated.

When the vapor of water is passed over red-hot coke and coal, and analysed, the resulting gas is found to consist, in a hundred volumes, of fifty-six of hydrogen, twenty-nine of carbonic oxide, 15·8 of carbonic acid, and light carbide of hydrogen only two-hundredths of one per cent. *It contains no olefiant gas whatever;* this experiment is quite conclusive against the use of water or steam. It is evident that there are no products of the decomposition of water by red-hot coal or coke that possess any illuminating power. It has often been proposed *to pass steam into the retorts during the distillation of coal, but such a proceeding could have no good effect, but the contrary.* When it is considered that fifty per cent. of the whole of the gases proceeding from the decomposition of water by red-hot carbonaceous matter is hydrogen, it must be evident that this product would not only diminish the light of the gas with which it was mixed, but would give out such an amount of heat during the burning of it as would render the use of such gas almost insupportable. The coal, then, should be dry; but it has been shown that air, passed between seams of coal, has been deprived of a portion of its oxygen, which must have combined with the carbon and hydrogen of the coal, and by so much have impaired its quality; further, it has been stated that coal and cannel are continually giving off gas—fire-damp—and this teaches that coal should be dried quickly and then used.

Distillation of Coal.—A few remarks may now be made on the changes which take place during the manufacture of gas by the distillation of coal in red-hot retorts. The nitrogen in gas is *entirely derived from atmospheric air*, admitted into the retorts during the charges, and by leakage in the apparatus, and is not a product of the decomposition of coal at all; it need not, therefore, be further dwelt upon.

The quality and illuminating power of the gas will be affected, not only by the quality, composition, and condition, wet or dry, old or recently obtained, of the coal or cannel, but by the degree of heat employed in its preparation, and the mode in which the operation is conducted. The chief products of the distillation are compounds of carbon and hydrogen, and these alone yield light; but of these, some are solids, others liquids, and some gaseous. The first two are of no value for the purpose of illumination, because their physical condition as solids and liquids precludes their use. The gaseous are three: one containing very little carbon—carbide of hydrogen—and, therefore, emitting very little light; the other two very rich in carbon—olefiant gas and volatile carbides of hydrogen—and giving light, though in small quantity. Mixed with these are found, besides the usual impurities—sulphide of hydrogen, ammonia, carbonic acid, *et cetera*—two gases, hydrogen and carbonic oxide, constituting the chief bulk of the mixed coal gas, which have been mentioned, but which are never evolved in natural operations. They are not necessary products of the process, but result from the mode of distillation.

The volatile hydrocarbons in coal gas, the exact nature of which has not yet been determined, and the proportions of which in the mixture are valuable, probably consist of propylen, $C_6\ H_6$, Faraday's gas, $C_8\ H_8$, and benzol, $C_{12}\ H_6$, with perhaps a portion of Mansfield's allyl. In Leigh's earlier experiments on coal gas, which had been made from a different cannel to what is now employed at the Manchester Gas-Works, he found, pretty uniformly, that each volume of the gas, condensable by sulphuric acid or chlorine, required four and a half volumes of oxygen for combustion; subsequently, he ascertained that, when richer cannels were used, the condensable gases required a still larger proportion of oxygen for combustion. The fact, that a greater amount of carbonic acid is produced on exploding the gas with oxygen, than would proceed from a body of the series $C_n\ H_n$, shows that some other hydrocarbon, the carbon of which exists in a greater ratio to the hydrogen than in this series, is to be found in coal gas.

When the number of equivalents of carbon in a compound exceeds those of the hydrogen, it is, within certain limits, liquid· beyond these limits, solid: thus benzol, $C_{12}\ H_6$, in which the carbon is double the hydrogen; toluol, $C_{14}\ H_8$; and cumol, $C_{18}\ H_{12}$, are liquid;—whilst naphthalin, $C_{20}\ H_8$; paranaphthalin, $C_{30}\ H_{12}$; pyren, $C_{15}\ H_3$; and chrysen, $C_{12}\ H_4$, are solid.

The carbides of hydrogen may be conveniently divided into three classes. In the first, the number of equivalents exceeds that of the hydrogen; they are very rich in carbon, as benzol; these are either liquid or solid, and would give great light could they be burnt, but yield much smoke. In the second, the equivalents of carbon and hydrogen are equal in the compounds, as olefiant gas, volatile carbide of hydrogen; these are gaseous, but condensable by great pressure and intense cold, and give much light. In the third, the equivalents of hydrogen exceed those of carbon; these are altogether uncondensable, and give little light. When coal and similar organic matters are distilled at a comparatively low temperature, the carbon has a disposition to pass off with little hydrogen; the liquid carbides of hydrogen are formed; there is much tar and little gas, but the latter is rich. As the temperature rises, the liquid carbide of hydrogen diminishes in quantity, and gaseous carbide of hydrogen increases; there is more gas and less tar. The heat still rising, the gaseous products become richer in hydrogen, and poorer in carbon; light carbide of hydrogen is formed in abundance; and at length, the temperature becoming still more elevated, pure hydrogen is evolved, as is always observed in the last hour's distillation in gas-making.

It is a well-known law of organic chemistry, that the higher the temperature, and the more advanced the decomposition of the substance, the simpler are the products.

When olefiant gas is passed through red-hot tubes, or lime, or, in fact, over any highly heated surface, it deposits a portion of carbon in a solid form, and escapes as a mixture of carbide of hydrogen and hydrogen. The same thing Leigh has proved of naphtha, which deposits carbon in like circumstances, and is resolved into simple products.

The affinity between carbon and hydrogen seems to diminish with the temperature.

Is it not probable, that in the distillation of masses of coal, compounds rich in carbon are first formed, the carbon being in excess of the hydrogen? as the product rises in temperature, it deposits a portion of its carbon, the equivalents of hydrogen become equal, and a rich gas is formed; but this, getting still hotter, deposits more carbon; the hydrogen is now in excess, the gas is poor and gives little light; the heat still increasing, the affinity between the hydrogen and carbon is entirely disrupted, the remaining carbon is deposited, and pure hydrogen given off. Certainly all this can be effected artificially; and that it is so to a large extent in gas-making, is evident from the thick lining of almost pure carbon which soon forms in the interior of gas retorts, and which must proceed from the decomposition of the gas by the red-hot surface—must be deposited from it, in fact. Still there are, probably, three products at least of the decomposition of a liquid carbo-hydrogen: solid carbon, a gaseous product containing much hydrogen, and a solid hydrocarbon having much carbon, the elements being divided amongst each other. When naphtha vapor is passed over red-hot quartz, it deposits carbon, gives off olefiant gas and light carbide of hydrogen, and forms a crystalline compound, naphthalin. With these facts, is it not reasonable to conclude, that there is a temperature at which, in the process of decomposition, olefiant gas and volatile hydrocarbon should be formed, and which yet should be unable to decompose these into compounds poorer in carbon, the intensity of decomposition being proportionate to that of the heat? The Editor agrees with Leigh in thinking there cannot be a doubt that there is such a temperature, but it must be far below that at present employed for the manufacture of gas. Let the present system of gas-making be examined, says Leigh, and the true source of the hydrogen and carbonic oxide, so invariably found in gas, and constituting so large a portion of its bulk, will be seen. It may be premised, that when carbonic acid is passed over red-hot coke, it is resolved into carbonic oxide, by taking up an additional equivalent of carbon.

When compact masses of coal are thrown in heaps, of a hundredweight and a half, into retorts heated to a bright redness, as is now done, they are exposed to two very different conditions: the surface of the mass, the exterior, in contact with the intensely hot retort, is instantly decomposed and charred; hydrocarbons, as olefiant gas, *et cetera*, are eliminated, which also, at this temperature, are partly decomposed and converted into light carbide of hydrogen and pure hydrogen, with deposition of carbon, which, with some undecomposed olefiant gas and volatile hydrocarbons, pass off from the retort. The interior of the mass, on the other hand, is for some time exposed to a very moderate heat, and a simple distillation is accomplished; those compounds that are formed at a comparatively low temperature, the heavy hydrocarbons, which would ordinarily be in a liquid state, are eliminated; a portion, rising into vapor as it reaches the hotter surface, passes off with the gases formed, and condenses again when it has left the retort in the form of tar; but that portion of the vapor which, in its passage, comes into contact with the red-hot surface of the exterior of the mass and of the sides of the retort, deposits a portion of its carbon, and is resolved into simple compounds, olefiant gas and volatile hydrocarbons, which themselves partly undergo the change already described. As the heat penetrates to the centre, and a red-hot mass of charred material of considerable thickness comes to surround the decomposing coal within, as happens towards the end of the distillation, the whole of the hydrocarbons, namely, light oils, volatile hydrocarbons, olefiant gas, and even light carbide of hydrogen itself, that are eliminated, are decomposed in passing over such an extent of heated surface, and pure hydrogen is almost alone evolved. The carbonic oxide, which is formed from the union of the oxygen of the coal, and of the air admitted with the carbon of the coal, is also partially decomposed during the whole of the process, but in an opposite direction; not by depositing carbon, but by taking up more, and being converted into carbonic oxide, which is evolved with the gas. These are the true sources of the hydrogen and carbonic oxide in gas; they are not necessary results of the distillation, but products of the decomposition of the distilled matter. It has been perfectly ascertained by Leigh and other chemists, that when olefiant gas is passed through a nearly white-hot porcelain tube, it is entirely decomposed, depositing the whole of its carbon, and giving off pure hydrogen.

The greater the heat employed, then, in the process of gas-making, above a certain limit—namely, that requisite for the decomposition of the liquid hydrocarbons—the greater will be the bulk of the gas, and the poorer its quality; the more light carbide of hydrogen, hydrogen, and carbonic oxide it will contain, and the less volatile hydrocarbon and olefiant gas. The analysis of the gas will, therefore, furnish a test of the excellence of the process employed in the manufacture, and a check on the workman, by exhibiting, in the relative amount of hydrogen, and of the illuminating hydrocarbon, whether the heat has been too great. A large quantity of gas may be made from coal, and very badly made. *The mere amount of gas produced is no proof of the excellence of the manufacture.*

Cannel yielding eleven thousand feet of gas per ton, of specific gravity 1·600, would furnish, for every hundred pounds distilled, about—

	Pounds.
Gas,	22·25
Tar,	8·50
Ammonia water,	9·50
Coke,	59·75
	100·00

These proportions will vary considerably, but still the numbers will represent a general average of produce. It has been shown above, that considerably more than one-third of the weight of the gas produced is distilled from the cannel in the form of tar, which contains, and is almost entirely composed of, the richest carbo-hydrogen, and very little oxygen; whilst the gas, as it contains only about forty-five per cent. of compounds of carbon and hydrogen by measure, amounting to about half its weight, has really only eleven pounds, or something near that number, of carbo-hydrogen, and of this only about four pounds will be olefiant and richly illuminating gases. So that the tar truly holds as much illuminating matter, or nearly so, as exists in the gas—not twice as much, as would appear from the numbers; for it must be borne in mind, that in the oils composing the tar the carbon exists in much greater proportion than the hydrogen—one of the lightest, benzol, being a compound of carbon, twelve; hydrogen, six—naphthalin and the solid carbides being represented by carbon, twenty; hydrogen, eight; and even higher proportions of carbon. So that, in the decomposition into illuminating gases, much of the weight must be lost in the form of deposited carbon. It will be now tolerably apparent, that in the form of distilled matters nearly one-half of the illuminating portion derivable from coal and cannel is lost to the gas. It is probable that a perfect system of gas-making would produce, from good cannel, a compound containing twenty per cent. of olefiant or other illuminating gases.

MANUFACTURE.—The process followed at the Liverpool gas-works, where the purest gas in the kingdom is produced, will first be cursorily described, so as to give the reader an insight into the manufacture; and, subsequently, the several parts of the apparatus will be treated of fully and separately.

The mode of decomposing the coal is a point of great importance; because, upon its successful results the advantages of gas-lighting, as far as respects economy and profit, principally depend.

The vessels employed for distilling or carbonizing the coal are called retorts, and may be either of cast-iron or fire-clay. Fig. 93 shows a general plan of the gas-works above-mentioned, and Fig. 94 a sectional view, in which A A represents the fire, and B B the retorts.

To introduce the coal into the retort a shovel is used; but in stations having small ones, the coal is placed in a long semicircular iron shovel, or scoop, which, being inverted, spreads it in thin layers, so that every portion of it may be exposed to the action of heat. In order that the required substances may be evolved in sufficient quantities, there must be the requisite amount of caloric; for if a piece of coal is to be extended to two hundred and seventy times its bulk, the heat applied must be equal to the force requisite to produce a separation and expansion of its equivalents.

The heat should be sufficient at the outset to extract the maximum quantity of gas. During the first two or three hours, the greatest proportion of tar is produced. This is accounted for on the principle, that the temperature in the retort is not high enough to maintain the material in a gaseous form, and hence the large amount of tar. If the retort should be too hot, some of the heavy gas will be decomposed, depositing part of its carbon, and forming light carbide of hydrogen; if, on the contrary, it is not sufficiently hot, there will be formed, as just stated, a large proportion of tar, and the gas will be light and of a bad quality. The charge should not be left in too long, as the last portions consist chiefly of hydrogen and carbonic oxide, both of which have a most injurious effect upon the quality of the products. The process requires five, six, or eight hours, according to the nature of the coal and the shape of the retort.

Previous to drawing the charge, the lid is loosened and a light applied; this precaution is necessary to prevent explosion, or what the stoker denominates a *rap*. At large establishments, the retorts are not suffered to lose their heat, but as soon as the incandescent coke has been taken out of them, are immediately replenished with fresh coal, and the operation renewed.

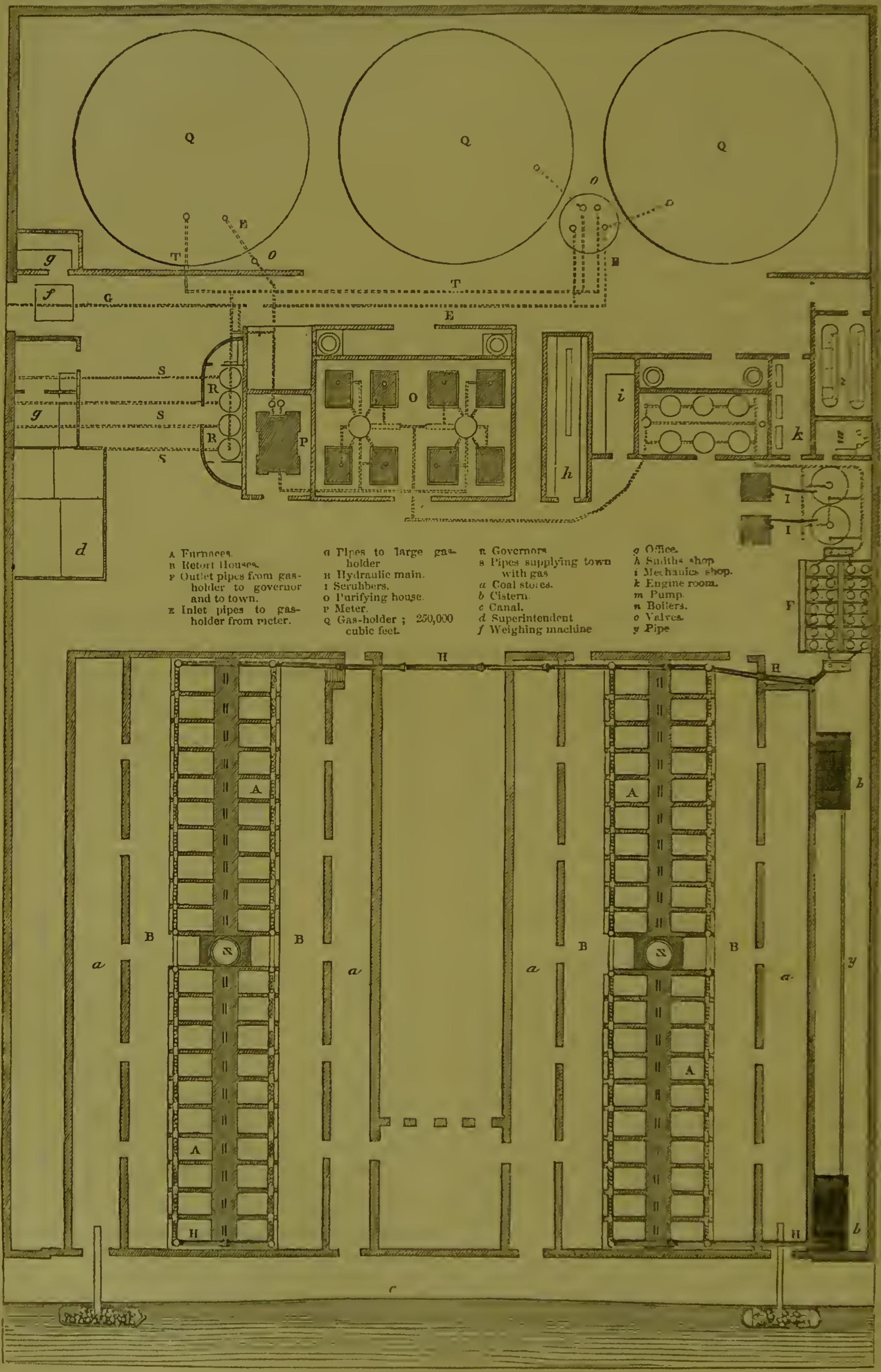
Inasmuch as the coke is withdrawn in a state of redness, the heat required to raise it to that temperature is lost. To remedy this, CROLL introduced the practice of burning the coke as fuel, immediately after its removal, and this plan is said to cause a saving of ten per cent.

The dense vapors which pass from the retort are conveyed through the ascension pipes, C, Fig. 94, into the hydraulic main, H H, which runs the entire length of the house, and to which all the retorts are connected. Its position must be perfectly horizontal; it is used to cut off the communication between the retorts, when one or more benches are charging or open. This is shown in Fig. 95. One end of it is perfectly closed by means of a flange, and the other has a similar one. On the top is attached a pipe, through which the gas passes to the condenser. In the outside of this end a piece of iron is placed, so that the water in the main is preserved at a certain height, and cannot sink below the proper level required for the operation. An enlarged view of this is shown at E, Fig. 96. The dip-pipes descend so far into the hydraulic main, D, as to be immersed in the water about three inches; by this means the gas is forced to pass through a quantity of liquid before it can enter the upper part of the main to escape, and becomes partly condensed, and deposits tar and ammonia, but, owing to its superheated state, portions of these products are still retained, and must be separated by further condensation. To effect this, the gas is conveyed into a double set of refrigerating pipes, F F—Fig. 94—closed at the top, and opening into a box, G, at the bottom, a section and plan of which are shown in Figs. 97 and 98. The latter receives two pipes, and constitutes one pair of the series which are united by a short connecting-pipe at the top, as seen in the drawing. The greater the quantity of cold surface the gas is exposed to, the more complete the condensation, and a state of stillness materially aids the deposition of the tar. Thence the gas passes through the scrubbers, I I—two large towers filled with paving-stones—and at the top of which one of the pipes, K K, for conducting water, which is kept continually percolating, is shown in the enlarged view of K—Fig. 99. The condensers and the scrubbers are relieved of their tar and ammonia by the cisterns, L L, which are conveniently placed under ground. The ammonia, being the lighter, floats at the top, and is therefore easily separated from the tar. In the articles AMMONIA and ASPHALT, the purposes to which both products are applied are enumerated. From the scrubbers the gas passes through the exhausters, M M M—a series of apparatus introduced into modern gas-works, for the purpose of drawing off the gas and relieving the pressure in the retorts. They are worked by a shaft, T, connected with the engine.

The gas then enters through a pipe, *b b*, into the chamber, N, a plan of which is given in Fig. 100. From this it is conducted, as shown by the arrows, through the dry lime purifiers, O O, where it parts with its carbonic acid and sulphide of hydrogen. It is next conveyed to the station-meter, P; thence to the gas-holder, Q; then into the governor, R, the principle of which is illustrated in Fig. 101; and, lastly, to the main, S, supplying the town with gas.

Whoever enters, says DODD, for the first time into a retort-house cannot fail to be struck with its appearance. The iron roof and floor—the absence of windows, machinery, and work-benches—the curious appearance of the walls, covered over with complicated iron-work—the darkness of the place—the appearance of the men,—all have an aspect of strangeness. But, at intervals of every hour or two, and especially at night, the visitor's attention is suddenly awakened to a startling scene going on within the building. A set of men are seen advancing to one part of the side apparatus; they turn the handles of what appear to be screws; several ex-

Fig. 93.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A Furnaces.
B Retort Houses.
F Outlet pipes from gas-holder to governor and to town.
E Inlet pipes to gas-holder from meter.
G Pipes to large gas-holder
H Hydraulic main.
I Scrubbers.
O Purifying house.
P Meter.
Q Gas-holder; 250,000 cubic feet.
R Governors
S Pipes supplying town with gas
a Coal stores.
b Cistern.
c Canal.
d Superintendent
f Weighing machine
g Office.
h Smiths shop
i Mechanics shop.
k Engine room.
m Pump.
n Boilers.
o Valves.
y Pipe

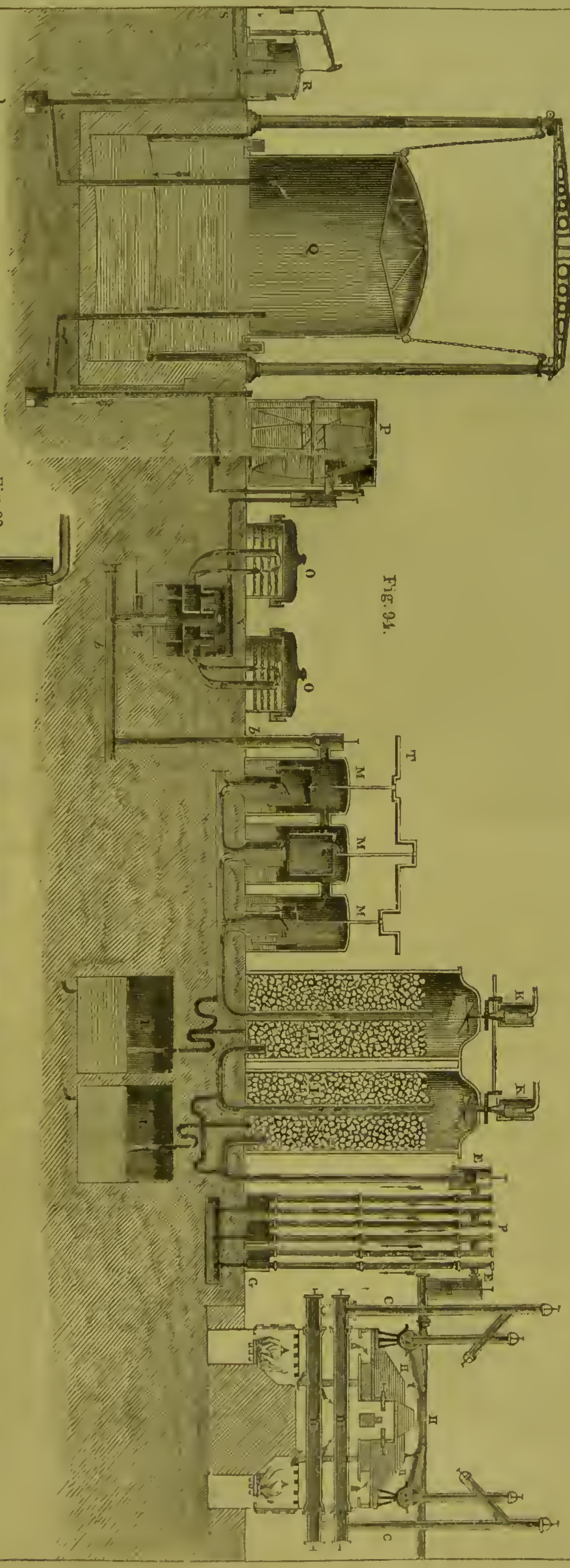


Fig. 94.

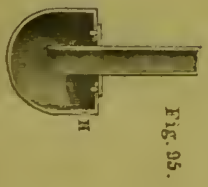


Fig. 95.

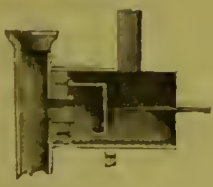


Fig. 96.

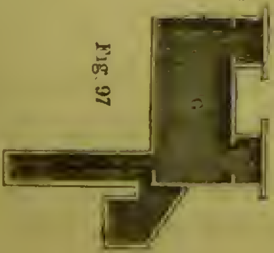


Fig. 97

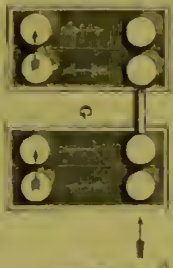


Fig. 98.

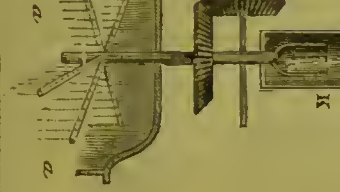


Fig. 99.

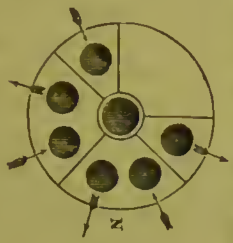


Fig. 100.

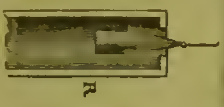


Fig. 101.

plosive reports are heard, followed by the removal of circular iron doors or covers, about a foot in diameter; a burst of flame then issues from each orifice from which a cover has been taken; and, on going in front of one of these openings, there will be perceived a mass of intensely burning coal, or rather coke, extending back to the depth of six or seven feet. Then will follow the removal, by means of rakes, of all the burning materials from each aperture; then the hissing and steaming consequent on the wetting of the coke by buckets of water; and, lastly, the re-charging of the heated cavity with fresh coals. It is not until after witnessing this series of operations that a stranger can rightly understand the arrangements of such a place. Fig. 102 gives some idea of the retort-house.

Fig. 102.

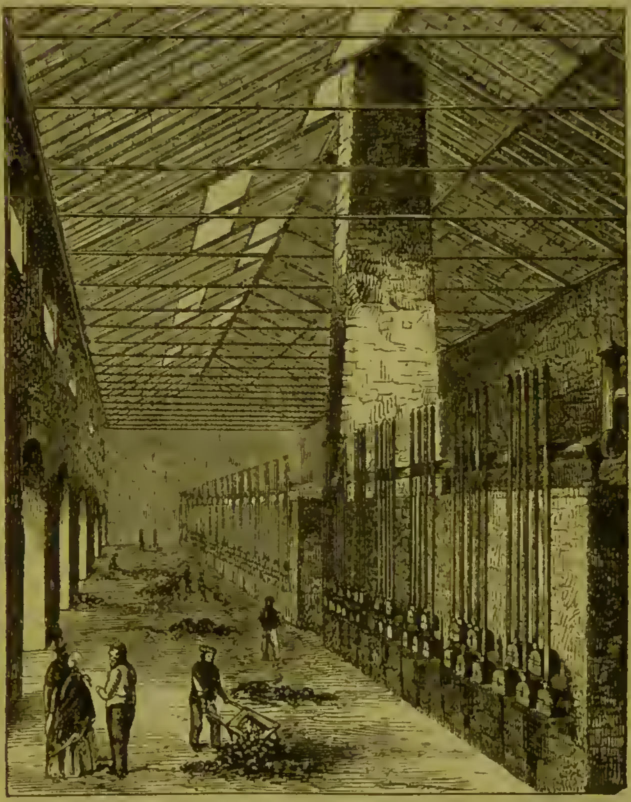
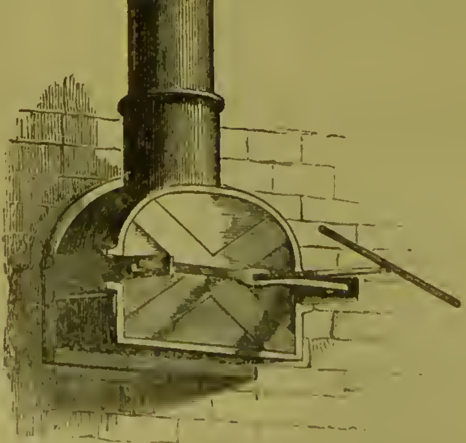


Fig. 103.



Retorts.—As the form of the retorts in which the coal is distilled, and the material of which they are composed, are matters of paramount importance, it will be desirable to enter fully into details with regard to them. They are usually of cast-iron, seven feet long, and one foot in diameter.

Tomlinson states that, before being used, they are tested by being placed in water, and then forcing air through them; if any flaw exist, it is detected by the air escaping in bubbles. Each retort is generally in two pieces, which are connected by flanges and screws —namely, the *neck* or *mouth-piece*, and the *body* or hinder part, which, by constant exposure to the fire, soon wears out, and requires renewal, while the mouth-piece is but little affected. The retort is charged and discharged at the mouth, which is closed by a lid, and fixed by means of a screw and a holdfast, the joint being made tight by a luting of clay, or refuse lime from the purifier. The gases which are generated from the coal escape from the retort by a wide tube, cast into the mouth-piece, and shown in Fig. 103, rising up therefrom. The best form for the body of the retort for obtaining a large quantity of gas in the shortest time, was long a matter of discussion.—*Tomlinson.*

That shape of retort would be best which would bring the whole charge into connection with the red-hot sides. Hence, at the suggestion of Prechtl, the original circular form of retort—Fig. 104—was soon superseded by the elliptical one—Fig. 105—and this has been improved by bending in the lower surface—Fig. 106. With the same length of 6·5 feet, exposed to the fire, one hundred and fifty pounds of coal, when they only half-fill the retort, will cover, in the round retort, a red-hot surface of ten inches in width; in the oval retort, a surface nearly of twelve inches. The layer

Fig. 106.

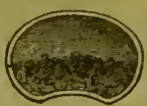


Fig. 105.

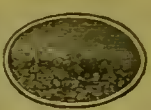


Fig. 104.

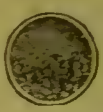
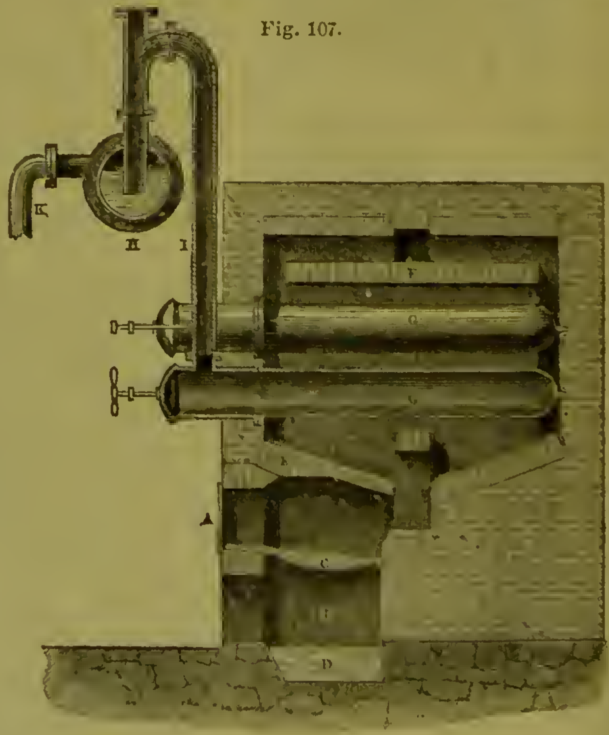


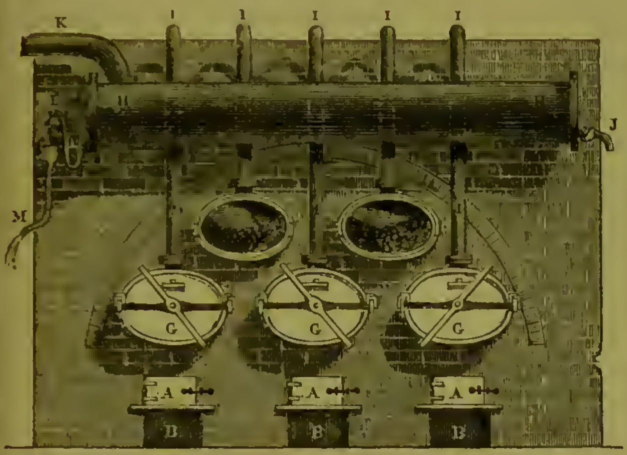
Fig. 107.



of coal, in the latter retort, is four inches thick, and about one-third nearer to the top of the retort than in the circular form. These advantages, which are self-evident, are strikingly shown in practice, the requisite time for heating being reduced to nearly one-half.—*Knapp.*

Fig. 107 shows the arrangement and position of the retorts, of which there are generally five placed pyramidally in one furnace. Fig 108 is a front view of the same. To the three fires of the furnace, A is the door, C the grate, and B the ash-pit, with a well, D—Fig. 107, for occasionally drying lime-mud; E is one of the three arches which pass transversely over each fire and divide the flame, F is a large arch overspreading the retorts, G G, against which the flame breaks and escapes at the side. The conducting tubes, I I, rise side by side above the furnace, passing behind a large horizontal tube, H, called the hydraulic main, and lastly turning over above it, enter it, dipping down nearly to the bottom. As this main, H, is filled with tar, the mouths of the tubes, I I, are closed, and there is no connection established between the separate retorts. One may, therefore, be opened and charged, without in the least interfering with the process going on in the other. The greatest portion of the tar separates from the gas in H, which latter passes off through K, whilst the former is carried away by the tube, L, curved for the purpose of keeping H half-full, through M, to a tar cistern, which is shown at L, Fig. 94; H can be completely emptied by means of the tap, J.

Fig. 108.



A very hot flame, mixed with an excess of unconsumed air—oxidizing flame—is unnecessary for the evolution of gas, and deleterious, on account of the rapid destruction of the retorts which it occasions; everything, therefore, depends upon a uniform, steady fire. The destruction of the retorts is incredibly rapid, and dependent upon several circumstances; besides the combustion caused by the hot air of the fire, the sulphur in the coal converts the surface into sulphide of iron, which melts off, and, lastly, the deposit of carbon in the interior, is of no slight importance. This carbon is partly in the form of hair-like deposit, partly stalactitic, from the dropping of tar, but generally occurs as a coating, one or two inches thick, in concentric layers, and combined with iron to form graphite. The specific gravity of these layers increases rapidly from the innermost layer to those on the outside, from 1·7 to 2·3. The outermost contain 1·72 per cent. of iron, the inner layers less; sometimes they are so hard, that they will strike fire with steel, and can be polished like glass. Carbon, sulphur, and the oxygen of the air, are, therefore, conjointly destructive of the retort. The retorts suffer most from the air that enters at the door when the fire is poked, and attacks them whilst red-hot. To protect them from this, the stoking-hole is sometimes situated at the back of the furnace, in a continuation of the chimney, when the noxious draft passes away without attacking the retort.

Fire-clay retorts are now extensively used, especially in very large works; and, from all the Editor can learn, they are superior to cast-iron in every respect, as regards duration and the great quantity of gas they are able to produce. One great advantage which they possess over iron retorts, is the facility with which the carbon that accumulates on their interior can be scraped off. Retorts made of this material, which are charged and drawn at both ends, and are therefore termed *through* or double retorts, have been lately very largely introduced; their superiority over single or back-to-back retorts consists in the amount of space gained by leaving out the partition walls, and also the thickness of the ends of single ones. In addition to this, when iron retorts are employed, they become so choked up with carbon, that the charge of cannel has to be gradually reduced as the area of the interior of the retorts decreases. In *through*-clays this is obviated; and in order to remove the accumulated carbon, it is merely necessary to leave the retort mouths open, thus allowing a current of air to pass through, and the carbon will peel off in flakes if touched with a sharp bar; a portion may also be consumed. An iron retort will afford, according to various authorities, about seven hundred thousand feet of gas, whilst the same length of a through-retort of the same diameter has been known to produce six times that quantity. The amount of fuel required to heat the through-retorts efficiently, is as yet undecided: some engineers give it as their opinion that the amount requisite is the same as is necessary for iron retorts, whilst others affirm that they need a much larger quantity. Should the clay retorts become by any means cracked, a mixture, composed of the following ingredients, is found to be an excellent cement:—

	Per cent.
Fire-clay,	42·5
Loam-sand,	42·5
Glass,	10·0
Chloride of sodium,	5·0
	100·0

This compound is ground well together with water. The principle of sealing up the gas by a water lute, or hydraulic joint, is, however, the same in both cases, and affords another instance of those beautiful contrivances for using one fluid in the management and manipulation of another, which is much lighter and more elastic.

The Pipes for connecting the Retorts with the Main.—The pipes leading from the retort to the hydraulic main are not fitted in the retort itself, but into a separate casting, termed the mouth-piece, which is commonly of the same size as the mouth of the retort, and is secured to it by a flange and bolts. The same kind of mouth-piece is used for clay retorts, which, instead of a flange, are provided with a ring, four inches in thickness and six in breadth, through which holes are cut to receive the bolts for securing the mouth-piece.

A bent pipe passes up from the mouth-piece to the hydraulic main, the straight part secured to it being called the stand-pipe, while the other straight part passing into the main is called the dip-pipe. The part connecting the dip and stand-pipe is named the bridge-pipe, and this part is usually provided with two bonnets, which can be removed when the pipe requires cleaning. The stand and dip-pipes vary in diameter from three to six inches, a very usual size being four inches. There are various modifications in the arrangement of pipes between the retorts and the hydraulic main. In England, the stand-pipe usually passes up to a height of four or five feet above the main, and is fitted at the top with a semicircular bridge, which connects it with the dip-pipe.

The Hydraulic Main.—This is a tube or trunk, H, Fig. 94, usually but not always of cast-iron, extending the entire length of the retort house, and varying from twelve to eighteen inches in diameter, and generally five-eighths to three-fourths of an inch in thickness, when made of cast-iron. Wrought-iron hydraulic mains are now beginning to be used, and will probably altogether supersede cast-iron, on account of their lightness and strength. These are usually made of larger diameter than the cast-iron, and put together in longer lengths. They are formed of three eighths of an inch boiler plate. The ring forming the main is composed of two circular plates, and one flat piece on the top. These plates are made of two breadths, namely, about three and two feet, and about five feet six inches in length. They break joint with each other, by having their line of division alternately on opposite sides of the main, which is constructed in lengths of twenty-three feet, and at each end of this length, there is a flange three inches wide. At the end of each length, and also midway, is a division plate seven inches deep in the centre.

The cast-iron mains are generally of such a length as to reach over two benches, and the joints are made with bolts and nuts, and iron cement, in the usual manner. In old works, the hydraulic main is usually a circular tube; but of late years, D-shaped mains have been frequently employed, generally with the flat side downwards.

The hydraulic main, when first brought into action, is filled to about one-half with water, but the tar contained in the gas which passes into it is deposited, so that the sealing liquid changes its character, and becomes nearly all tar.

The hydraulic main being filled to the above height, the end of the dip-pipe passes through the water to a depth of three or four inches. The gas from the retorts is then conveyed through the dip-pipes, and bubbles up through the water, till it arrives in that part of the main above the surface of the liquid. The hydraulic main, therefore, is the first receptacle in which the gas is collected, after its separation from the coal.

It perhaps will not be out of place to call attention, in passing, to the simple yet admirable contrivance exhibited in this apparatus, which is partly filled with a dense fluid for the purpose of forming a perfectly air-tight and gas-tight chamber, and cutting off all communication from this chamber to the retorts, while the passage of gas from the latter to the former is entirely free and open. Its *modus operandi* will be evident, if it be considered that the extreme lightness of the gas will always cause it to pass upwards through the tar, while, once arrived over its surface, it has no power whatever to displace the tar, and pass backwards. This exquisite contrivance is termed the water-joint, and the hydraulic main constitutes its first application in the gas manufacture. It is by this method that the chemist is enabled to store and confine his gases in the receivers of the pneumatic trough, and thus, by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtilty, infinitely excels every scheme of mere mechanical fitting. It will be seen hereafter how largely this valuable principle of sealing up the aeriform fluids by denser ones, through which they can pass in one direction but not in the other, has been applied in the purifier, the gas-holder, and, in fact, in everything connected with the collection, storing, and distribution of the gas. At present, it may be sufficient to point attention to the value of this property, derived from the different densities of fluids, which gives both to the chemist and manufacturer a power over the aeriform bodies, which they could not hope to obtain by any other means.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own retort, and the liquid effectually prevents its return. However numerous may be the pipes entering into it, whether they contain gas or not, and whether the retorts are working or not, it is impossible that any gas delivered above the surface of the tar in the main can escape back.

The length of the dip-pipes should not be less than three feet, and is frequently made as much as five, in order to prevent the tar rising in the dip-pipes connected with the empty retorts as high as the bridge-piece. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the empty dip-pipes, but this seldom equals three feet. As the hydraulic main is generally half filled with tar, its diameter must be so regulated that the latter forced up into the empty dip-pipes will not so far diminish the depth in the main as to uncover the ends of the former, because this would simultaneously unseal every one of them, and the gas would immediately escape.

The hydraulic main is sometimes placed in the solid structure of the brick-work over the retorts, but more frequently a little in advance of the ends, in which case it requires to be supported by columns. The hydraulic mains at the Great Central Gas-Works, London, are in the shape of a reversed D, eighteen inches in height and the same in width. There is one on each side of the stack retorts. They are cast in lengths of nearly ten feet, so as to reach over one bench of retorts, and the joints are placed over the centre of the arches. Their thickness is five-eighths of an inch, with a two and three quarter flange at the ends of each length. The upright pillars to support the mains are hollow columns, seven inches at base, six inches at top, and five-eighths of an inch in thickness. A pillar is placed in the centre of each length, and the opposite pillars are tied together by bars of inch-round iron stretching entirely across the bench of the retorts.

Each length of the hydraulic main is usually provided with a partition, the top of which is level with the surface of the fluid, and the object of which is to keep it to the same height in every part of the main. Of course, where so much depends on the effective sealing-up of the ends of the dip-pipes, every care must be taken to fix the apparatus in a perfectly horizontal position, from end to end. When the hydraulic main is cast-iron, the holes to receive the ends of the dip-pipes are cast in it, and the flanges of the same are secured to the main by nuts and bolts, the joints being made with the usual cement, such as that employed for attaching the mouth-pieces to the retorts. When the main is of wrought-iron, the top is formed by a flat piece, to which the wrought-iron circular part of the main is attached by rivets, and in this flat piece the holes for the dip-pipes are cut by hand. One end of the hydraulic main is closed by a plate having the same section at the outside flange of the main, to which it is bolted and secured by iron cement. A similar plate is also bolted at the other end of the main, but this plate is provided with an orifice usually about half the diameter of the main itself. The lower part of this orifice is immediately above the level of the fluid in the hydraulic main, and the orifice itself corresponds with the exit-pipe, which conveys away the gas to the condenser. The flange of the exit-pipe is bolted on to the perforated end-plate of the main. It is usually provided, soon after leaving this apparatus, with a descending pipe to carry off the tar into the cistern below the condenser. The lower end of this descending pipe must be sealed either by its dipping several feet into the tar of the cistern, or into a small vessel which communicates with the latter. The descending pipe to carry off the tar is not absolutely necessary at this place, because the same office is sometimes performed by the siphon-pipe at the first bottom bend of the condenser.—*Hughes.*

Condenser and Scrubber.—A separate account of these is unnecessary, as the reader will fully understand their use and purpose from the description given of them at page 133, as well as by referring to them on the general section, F I K, page 135, and enlarged view, Fig. 99.

The Exhauster.—In describing this apparatus, which has been introduced into modern gas-works for the purpose of drawing off the gas and relieving the pressure in the retorts, Mr. HUGHES gives some interesting particulars, which are appended. The modern refinements insisted on with reference to the purity of the gas, all contribute to increase this pressure, as, every time the gas passes through a fluid of greater density than itself, a resistance is occasioned, which adds to the pressure on the retorts, and this, at length, becomes so great, that means must be resorted to for diminishing it. In the first place, the contrivance of sealing the dip-pipes in the hydraulic main, requires the gas to force its way through several inches of tar before it can escape from the retort, and this is the first obstruction it meets with. In many works where dry lime is used in the purifiers, the gas is conveyed through water in the wash-vessel, where the gas is again resisted, and the pressure of course increased. In the dry lime purifiers and in the scrubbers, it is not considered that any sensible hindrance is opposed to the passage of the gas, but in some works both a washer and a series of wet lime purifiers are used, in which the force imposed becomes considerable, and an exhauster is found almost indispensable. The weight of the gas-holders also adds materially to the pressure in the retorts.

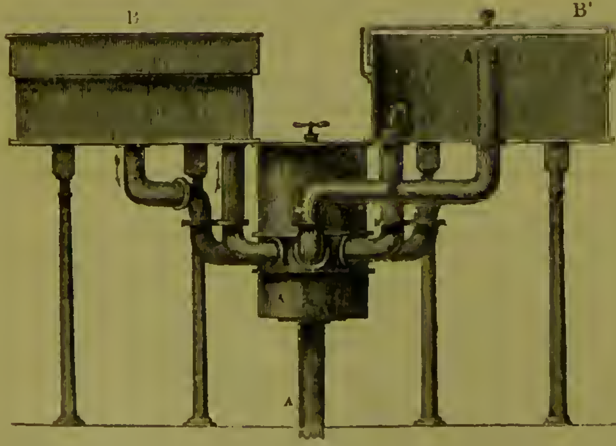
About twelve years ago it was ascertained by Mr. GRAFTON, in the course of some experiments at Cambridge, that the carbonaceous deposit in the retorts was due almost entirely to the pressure on the gas. Previously to this discovery, it was generally considered by the most scientific authorities that the carbon was due to high degrees of heat, and too great an extent of heating surface. In addition to the injury of this deposit to the retorts themselves, causing them to burn out with great rapidity, and the expense of frequently removing it, there is every reason to suspect that some of the very best constituents of the gas, namely, the volatile carbides of hydrogen, are decomposed and condensed in the deposit, and that the gas is thereby much impaired in quality. In addition to this, the pressure causes an increase in the quantity of tar, an effect which never takes place except at the expense of the gas. Mr. GRAFTON conducted his experiments in such a way as to show very practically the truth of the conclusion he had arrived at. By increasing the pressure till it became equal to a column of fourteen inches of water, he produced in a single week a layer of one inch thickness, and at the expiration of two months it had filled up nearly one-fourth of the retort. During this experiment an accumulation weighing ten hundredweight and twenty pounds was produced by the carbonisation of sixty-seven tons of Wall's End coal. Another trial, under entirely opposite conditions, was then made, all pressure being taken off except that arising from half-an-inch dip into the fluid of the hydraulic main. Under these circumstances, when the retort was again worked with the same description of coal for four months, scarcely any deposit had taken place.

The earliest form of exhauster used was a pump on the principle of the Archimedian screw, which was used for pumping the gas from a higher to a lower point, level with the surface of a small reservoir of water. The screw revolves in an opposite direction to that required for pumping up or raising liquids, and, at each revolution, the upper mouth of the helicoidal canal takes in a certain quantity of gas, after which follows the water. The gas descends along the spiral canal of the screw, in proportion to the rate of revolution in the latter, and having reached the lower extremity of the canal, passes off by a pipe, with an excess of pressure, measured by the height of the surface of the water above the lower extremity of the screw.

Another kind of extractor, which does not require so rapid a movement as the Archimedian screw, consists of a circular drum with four divisions, formed by curved plates proceeding from the centre to the circumference. The wheel revolves in a cistern filled with water to the height of three-fourths the diameter of the wheel; and each of the chambers, formed by the divisions, carries down below the surface of the water a certain portion of gas, which is delivered out of the drum into a pipe passing off at the level of the centre of the wheel. This pipe opens into a chamber containing water about an inch higher than the upper surface of the pipe, and the difference of level between the water in the cistern and in the chamber which the gas now occupies indicates the difference of the pressure. If the force be not sufficiently reduced by passing the gas through one drum of this kind, it goes on to a second or a third, till the required diminution has been attained.—*Hughes.*

Probably the most improved form of exhauster is that used at the Liverpool works, of which there are two sets, of three each, in operation. Exhausters become indispensable where clay retorts are employed, these being porous in their nature. They necessarily take up some space, but repay the outlay, as the oscillation shown on the inlet pipe does not alter more than half-an-inch, whilst other exhausters are known to vary many inches. Their construction is very simple. A pipe from the scrubbers runs under the three exhauster cylinders, with branches to reach to the height of three feet; at the top of the branch pipe there is a valve, and a holder of sheet-iron fits loosely over this, which has also a valve upon it. The space between the inlet pipe and outer cylinder is filled with water, in which the gas-holder works. When the latter ascends, the gas is drawn through the inlet valve, while that affixed to the gas-holder is closed by pressure from above; on its return the upper valve opens and the lower one closes. Each holder discharges at every revolution of the shaft about eighteen feet, and thus the gas is pumped from the retorts. Each cylinder is connected to the other by branches, placed near the top for the purpose of passing the gas through the purifiers, to which it is guided by the centre valve. They are worked by a shaft, T, connected with a steam-engine, as shown in Fig. 94.

Fig. 109.



The Centre Valve of Purifiers.—At the majority of works as many as sixteen or even more valves are used for the purpose of guiding the gas into and out of the purifiers. But, by the adoption of one centre valve, as is done in the Liverpool works, the necessity for a number is obviated.

Fig. 109 represents a front view of this most important part of the role of the gas-making apparatus, in which one purifier, B, with which it is connected is shown in elevation, and another, B′, in section. Fig. 110 is a plan of the same indicating the position of the four purifiers, B B′ B″ B‴, and the inlet and outlet pipes to and from each, by which the gas is made to traverse the whole. In the general view—Fig. 94—this valve is seen in section, and Fig. 111 shows it more perfectly. In the elevation and plan, Figs. 109, 110, A is the valve, which is so constructed that the gas entering it by the inlet pipe, A′, passes through an opening, as shown at *a*, Fig. 111, and thence flows through a conduit to

Fig. 110.

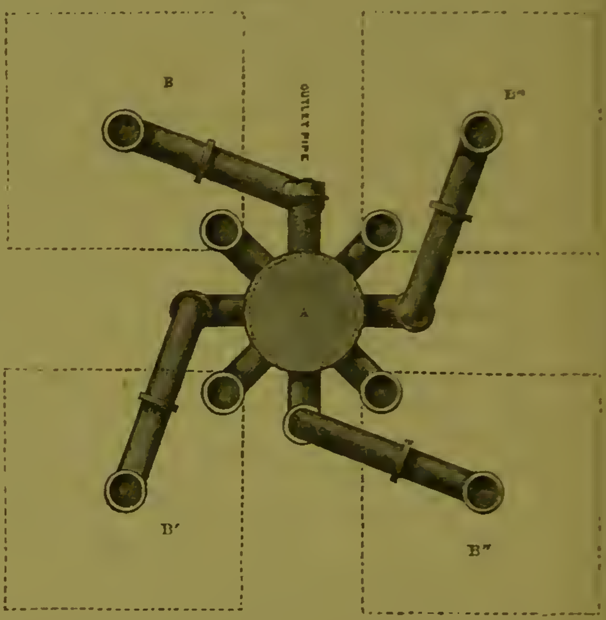
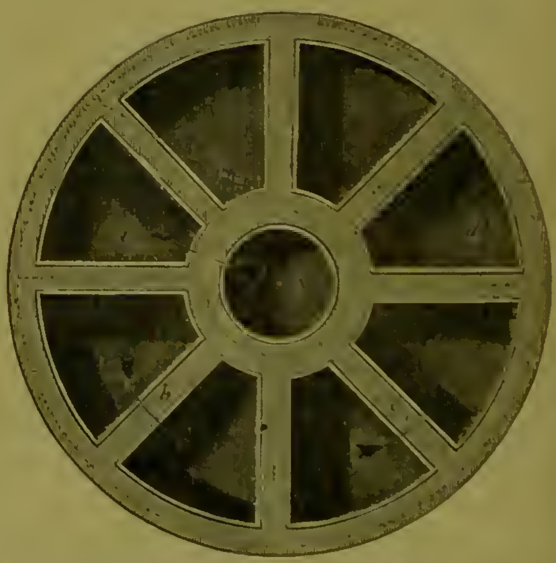


Fig. 111.



the first of three purifiers it has to traverse; the outlet which conducts it to division *b*, enclosed by the dotted line, causing it to pass into the inlet of the second purifier; the same arrangement answers for the outlet of second and inlet of third purifier. From that of the third, it enters through *d* to the division for one pipe, at the top of which there is an opening equal to the area of the pipe, through which the gas enters the upper part of the valve box. From this branches a duct which conveys the gas to the meter, as shown at P, Fig. 94. The blank division represented in the plan—Fig. 111—throws out of action the fourth purifier.

Circular pipes would answer all purposes as well as the rectilinear ones shown in the drawings, but a larger box would be required.

LIME PURIFIER.—Of all the substances which have been resorted to for the depuration of gas from sulphur compounds and carbonic acid, lime is the most universal, and the choice does not arise from its cheapness, but more on account of its superior effect in arresting those products which deteriorate illuminating gas.

It is employed in two states: in the one case the apparatus is termed the wet lime purifier, from the lime being made into a cream with water, and used in this condition; the other is known as the dry lime purifier, in which quick lime, barely slaked, is resorted to. Their comparative efficiency is matter of dispute among gas-makers.

Both these have an unequal repute for efficiency among gas-makers; but their merits will be best made known to the reader by giving a few brief descriptive sentences upon each.

Wet Lime Purifier.—Fig. 112 is an elevational section of a lime machine, and Fig. 113 a plan through *d d* in Fig. 112. A is the inlet pipe, through which the gas passes into the chamber, B, which is four feet diameter, jointed to the lid of the purifier, and supported upon two cast-iron beams, C. On to the bottom flange of this chamber, a circular ring of thin wrought-iron plate is riveted, of such a diameter that its outside rim will be within five inches of the tank of the purifier. D is a hoop, supported from the tank by bolts, *d d*, *et cetera*, having its upper edge level with the before-named plate, and its lower edge four or five inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas—after having overcome the pressure of the column of water in the tank, *plus* the pressure in the gas-holders—will pass, and bubble up through the lime-water.

Fig. 112.

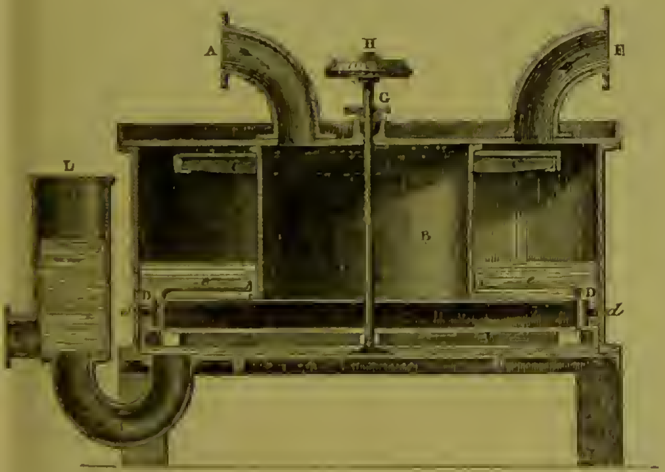
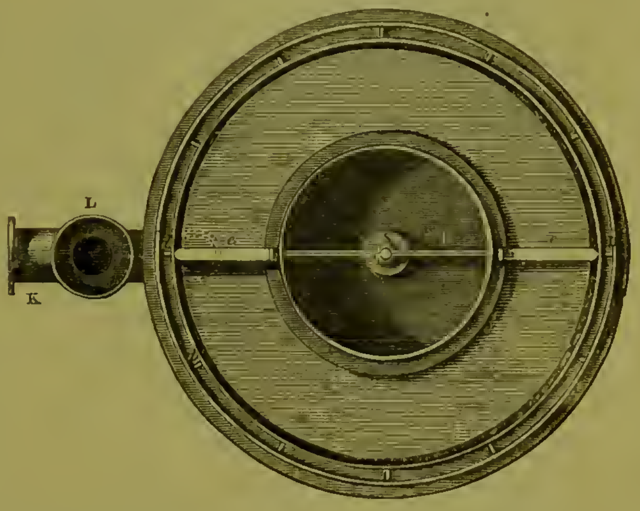


Fig. 113.



E is an arm made to revolve on the spindle, S; the parts *e e* of this arm continue through the aperture and over the ring, serving to keep the lime from settling, or obstructing the passage of the gas. F is the outlet for the purified gas. G is a stuffing-box, through which the spindle, S, passes. H, a mitre-wheel, connected to a water-wheel or steam-engine, for turning the spindle. I is a pipe, through which the lime-water is drawn off, when it has become saturated with the impurities of the gas. It will be observed, that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flange of the pipe, K, without suffering the gas to escape along with it, because a column of water will remain in the tube, I, equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tube, namely, twelve inches, which is always more than sufficient to overcome the pressure of the gas in the purifier, when the valve on the inlet-pipe, A, is closed, which should be done before that at K is opened. L is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity of water required; when the machine is at work, the column contained in the vessel will be higher than that in the tank, by the pressure of gas in the gas-holders, usually about three inches.

At the end of 1813, an explosion of a serious nature took place at the Westminster station, owing to a volume of gas escaping from the purifier, which was placed in a building near the retort-house, coming in contact with the flues of the retorts. The windows of several houses in the neighborhood were shattered, and Mr. CLEGG was severely injured. The recurrence of such an event was afterwards guarded against, by drawing the refuse lime-water through a bent pipe, as shown above, always containing sufficient water to seal it.

The lime-water may be mixed in a cistern—having its bottom *above* the level of the water in the purifier when filled, and furnished with an agitator worked by hand—and drawn off by a hose into any of the machines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every five bushels of paste-lime about one hundred and twenty gallons of water must be added. The size of the lime machines ought to be so regulated, that they will contain sufficient lime-water to purify the quantity of gas made in twenty-four hours, without having occasion to fill them higher than the water-line shown in the engraving.

Four lime machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, shut it off, and open a third, leaving the second to perform the duties of the first, and so on. The following extract from Mr. Clegg's journal expresses his opinion on the construction and use of lime machines:—

The grand principle in the construction of a lime-water purifier, is to divide the gas as minutely as possible, at the same time avoiding unnecessary pressure. If the machine be well constructed, seven or eight inches pressure in the machine is quite sufficient. Two sets are necessary, in order to have a pair clean and ready for immediate use. The practice of working the contents of the vessel over again, by passing them from one to another, is mistaken economy.

The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of eight inches, the computation is easy. Four thousand five hundred cubic inches of hydrate of lime —which, as has been before stated, is the quantity produced by reducing one bushel, or two thousand one hundred and fifty cubic inches of quicklime—mixed with forty-eight gallons of water, will purify ten thousand cubic feet of gas, if properly applied.

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary to *test* the gas in its progress through the various purifiers. In some cases it is advisable to use the test every twelve hours, or oftener, in districts, for instance, where coal is of inferior and various qualities. Every morning, as soon as the superintendent arrives at the works, he ought to test the action of his purifiers, more especially if he has received a fresh supply of coal or lime. It is necessary only to drop a piece of paper into the plumbous solution, and hold it to the escape-hole of the purifier. The slightest coloration indicates impurity.

Dry lime purifier consists of a square iron box—two are shown at o o, Fig. 94—six feet long by five feet wide, and three deep. The inlet pipe is eight inches inside diameter, and enters at the bottom of the purifier. A few inches above its mouth is fixed a plate about two feet square, which serves the purpose of distributing the gas and preventing any of the lime falling into the inlet pipe. The purifier contains three trays or sieves placed six or eight inches apart, and resting on snuggs cast on the inside of the purifier: each tier contains four trays, each tray being about two feet eight inches by two feet four inches, so that one purifier contains in all twelve trays or sieves, the bottom of each being composed of round rods, five-tenths of an inch diameter, placed about half an inch apart. The top of the purifier is an inverted box, six feet by five, and with sides and ends ten inches deep, fitting into a water lute twelve inches deep, so that the gas is enclosed by a seal of at least ten inches in depth of water; the outlet pipe passing out of the lid of the purifier is eight inches inside diameter, and is made in the form of a semicircle, the inside diameter of which is two feet; the other end of the semicircle joins another pipe that is fixed. Each end of the semicircle outlet pipe dips into an annular space containing ten or twelve inches depth of water, so as to form a water seal similar to that described for the cover of the purifier. These water joints greatly facilitate the removal of the semicircular pipe and the cover of the purifier whenever required for the purpose of cleaning out or otherwise, without breaking any solid joint or doing injury to any part of the machine. Mr. Clegg states that two bushels of the hydrate of lime will spread over a surface of sieve equal to twenty-five square feet, with a depth of two and a half inches, which, in practice, is found about the best thickness; and that this quantity, which is equal to one bushel of quick-lime, will, in some places, purify ten thousand cubic feet of gas, while in other places double the quantity of lime will be required.

In most of the French gas-works the hydrate of lime is placed upon beds of moss, which are first spread on the trays, or the latter contain alternately a layer of moss and one of lime. The use of the moss is to subdivide the gas into the thinnest possible sheets and streams, so that every particle of it may be brought into contact with the lime.

The purifiers generally used in the French gas-works are from three to four and a half feet in depth, and they are generally made circular, from four to eight feet in diameter, according to the size of the works; in these are placed three or four trays, which contain layers of lime and moss. When the lime is spread upon moss, it is usual to employ rather less than a bushel of lime per square yard of purifier. In most of the French gas-works the quantity of lime used for purification is at the rate of two and a half bushels per ton of coal, which yield, on an average, less than seven thousand cubic feet of gas per ton. The usual calculations with them is, that a purifier with an area of one square metre, or ten and three-quarters feet, is required for every ten hectolitres—two thousand eight hundred pounds—of coal distilled. This proportion is nearly at the rate of one square yard of purifier for each ton of coal distilled. The calculation is made on the quantity of coal distilled in twenty-four hours, this being the interval at which the lime in the purifiers requires to be renewed. It is also made on the supposition that the purifiers contain three layers of lime, so that the proportion becomes three square yards of screen containing lime for every ton of coal distilled in twenty-four hours. The cover of the purifier is made of light boiler plate, provided with a border or rim, which dips into a ring surrounding the purifier, and filled with water, so as to make a perfectly hydraulic joint. The cover is also fitted with handles, by means of which it can be removed when the lime requires to be renewed.

As regards the merits of both these methods, it may be remarked that the dry lime purifier is now almost invariably preferred, more especially in large towns, for several reasons which may be negatively enumerated:—it does not cause nuisances by evolving a foul stench to the same extent as the other; it is not so difficult to get rid of as the spent lime water, nor does it offer so much resistance to the passage of the gas, all of which qualifications are of sufficient importance to entitle it to the preference.

The lime removes from the gas carbonic acid about two per cent., and sulphide of hydrogen about one per cent., varying with the nature of the coal and its dryness. If the gas be properly purified, it ought to return good answers to the following tests:—A paper dropped in a solution of acetate of lead, and held in the gas, will turn black if sulphide of hydrogen be present; if the gas be passed through lime-water, a milkiness will be produced with carbonic acid.

Station Meter, or *Measurer*, is used for the purpose of ascertaining the quantity of gas produced from the coal; likewise as a check upon the men's work; and also for comparing the gas sold through the consumer's meter with that delivered from the works. The principle upon which it is constructed is as follows:—The part of the meter by which the gas is measured is called the drum, shown at P, Fig. 94; it is a cylindrical vessel, supported at the front and back by an axis, and divided into four separate compartments. These are so contrived, that whilst the gas is entering on one side through the inlet-pipe, it is passing out at the same time from another compartment at the opposite end, and, in its attempt to escape through the water, imparts a rotatory motion to the drum proportioned to its capacity and the quantity of gas allowed to pass through in a given time. The primary cause of this motion is the impulse communicated to the gas from the retort, technically called pressure. The action of the meter depends on its being filled to a certain height with water, over the surface of which the gas is transmitted; the use of the water is to close the aperture through which the gas enters the drum, and it also gives the latter a steadier motion.

At the front of the meter a series of wheels are worked by a shaft communicating with the axis of the drum, which, by means of the index, are registered in cubic feet—from ten to ten millions feet of gas manufactured during any period. The station meter employed at Athol Street, Liverpool, is constructed to register seventy thousand cubic feet per hour—one revolution of the drum will pass about six hundred and fifty. It is the largest of the kind ever made. Fig. 114 is a front view of it. On the face is a *tell-tale*, which serves the purpose of pointing out every irregularity in the production of gas during the twenty-four hours.

The following accurate description is given by Tomlinson:—In the centre of the *dial-field*—Fig. 114—is fixed a circular plate connected with a train of wheel-work, set in motion by an enclosed drum, through which the gas passes, indicating tens of thousands, hundreds of thousands, millions, and tens of millions of cubic feet of gas. Upon this round plate is fixed a disc of paper, divided into twenty-four parts, with subdivisions. Suppose the meter to register three hundred thousand cubic feet in twenty-four hours, and the plate to be connected by wheels in the ratio of three to one to that index, which marks one hundred thousand in one revolution; it is evident that the distance travelled by one of the twenty-four divisions of the plate from a certain fixed point, will indicate the quantity of gas made in one hour, or $\frac{300,000}{24}$ = twelve thousand five hundred cubic feet. Above this divided disc is a timepiece, to the minute-hand of which is attached a detent, furnished with a pencil, pressing by a spring upon the disc. As the minute-hand of the timepiece revolves, the pencil, by means of a guide fixed to the meter-case, is regulated, so that in the first half-hour it will make a vertical line upon the paper, in length equal to the diameter of the circle formed by the minute-hand, measured from the centre to the point at which the detent is fixed; in the second half-hour the line will be retraced by the hand rising again. This arrangement supposes the divided disc to be stationary; but, as it is made to revolve on an axis, which is also the axis of the internal drum, set in motion by the gas, the pencil will make a series of curved lines, meeting the divided circle of the disc every hour, and the distance travelled from point to point will mark the number of cubic feet of gas made during every hour

Fig. 114.

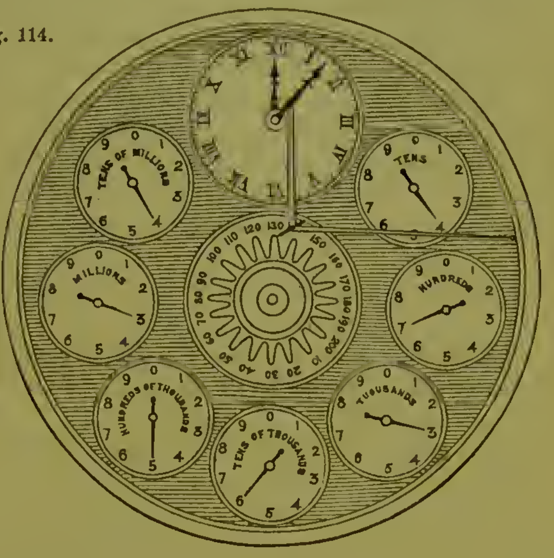
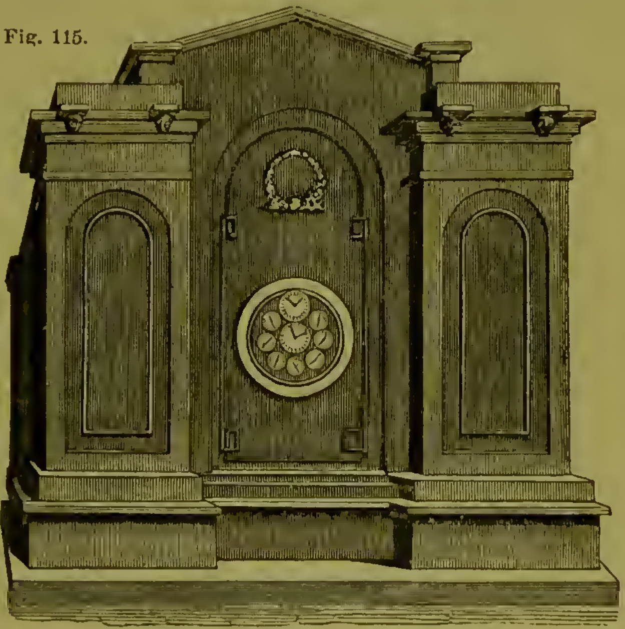


Fig. 115.



of the twenty-four. If the production of gas is regular, the figures formed by the pencil will be so also; if, on the contrary, any neglect has occurred, the irregularity of the figure will detect it, and point out the hour and the amount of difference; because, if the speed of the revolving disc be decreased, the figure formed will approach nearer to the straight line; if increased, the points of intersection upon the divided circle will be further apart. The case of the station-meter is usually greatly ornamented, and bears an appropriate inscription.—*Tomlinson.*

Gas-Holder.—The next subject for consideration is the gas-holders, or vessels in which the gas is stored ready for delivery into the mains, which distribute it throughout the districts to be lighted. These vessels were originally termed gasometers, which name is even sometimes now applied to them; but as they have nothing whatever to do with the measurement of gas, but are merely vessels of capacity, the simple name of gas-holder appears more expressive and appropriate.

The earliest gas-holders were made in the form of cubes or parallellopipeds; but there were disadvantages in this shape, independently of the waste of material required to construct them of this form, as compared with that for a circular one of the same capacity. The corners and angles of the square figures were also found to need bracing, and other precautions were necessary, in order to render the resistance uniform. Wooden tanks were also at one time made for the lifting part of the gas-holder to work in, but this was at a time when they scarcely exceeded in size some of the large vats or backs in use at the great porter breweries. The construction of these wooden tanks was, in fact, entrusted to the back makers, who used to guarantee the duration of the vessel for some period of time agreed on. They were, in consequence, generally constructed in a substantial manner, but it is evident that the rapid increase which took place in the size of gas-holders required the adoption of a different material than wood. When a deputation from the Royal Society, with Sir JOSEPH BANKS at its head, visited the gas-works of the chartered company in Westminster, about the year 1814, they strongly recommended government to restrict the company from constructing gas-holders exceeding six thousand feet in capacity, to be confined in very strong buildings. When Mr. CLEGG published his work in 1841, he says *gas-holders are now constructed to contain two hundred and fifty thousand feet.* In 1853 all the new gas-holders of the Great Central Gas Consumers' Company contained four hundred and twelve thousand feet, and there is one in Philadelphia one hundred and forty feet in diameter, and seventy feet high, capable of containing more than a million cubic feet.

The modern gas-holder is a cylinder of plate-iron, made of sufficient capacity to contain the maximum quantity of gas produced in twenty-four hours; and in very large works, where several gas-holders are used, the joint capacity of all should be equal to this maximum production. In many gas-works the capacity of all the gas-holders somewhat exceeds the consumption of the longest night, but it is believed this excess in capacity is unnecessary. The cylinder which contains the gas has no bottom, or it may be described as a cylinder inverted over a cistern of water, both the inlet and outlet pipes having their orifices above the surface of the water, so that the gas is hermetically sealed up within the holder, and can only escape through the outlet pipe. The mode in which gas is stored in the gas-holder bears a very exact analogy to that of collecting and storing pursued by the chemist in the laboratory, where the jar to be filled is inverted over a trough containing water, and the gas admitted into it by a bent pipe passing up through the water. In the chemist's method, however, the jar or gas-holder remains fixed, while the water is displaced by the gas; in the gas manufactory, on the other hand, the water is not displaced, but the gas-holder is raised by the gas flowing in.—*Hughes.*

The Editor deems a further explanation of this apparatus unnecessary. The reader will have a very good idea of the mode in which it is suspended by referring to Q, Fig. 94. Mr. ALFRED KING states that the pressure on the gas-holders varies from three to five inches—columns of water—but the distributing pressure, which is regulated by an instrument called a governor, about to be described, alters, according to the elevation of the district supplied, and the hour of the day or night, from four-tenths of an inch to two inches.

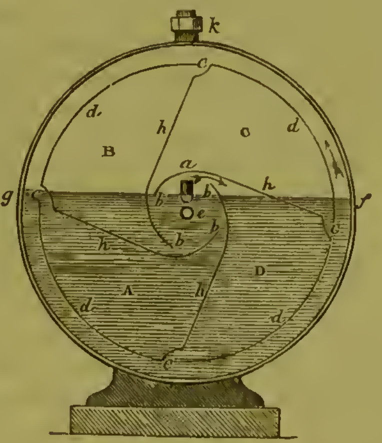
The Governor.—This is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gas-holder and the principal main pipe, in order to regulate the pressure of gas admitted into the latter, and acts quite independently of any irregularity due to the unequal action of the gas-holder, or to other causes. The governor is important in another point of view, namely, where a town has several different stages of elevation, and where, without some contrivance, the pressure of gas passing through the mains would vary very much on each different stage. It has been found by experiment that the pressure in a main varies at the rate of one hundredth of an inch for every foot of rise or fall.

In the case of a district being below the works, a governor is seldom necessary, the works being generally, as a matter of convenience, placed at a tolerably low level; and it is found practically that a district lying even thirty feet below the works may be lighted without the intervention of a governor to increase the pressure, as the diminution due to the difference of level would be only three-tenths of an inch of pressure. But governors are especially necessary in towns, such as Bristol, Bath, Edinburgh, Liverpool, Lincoln, Nottingham, Exeter, and many others which have different stages of elevation: because the gas, as it reaches the higher part of the town, will act with so great a pressure as to produce very serious leakage in the pipes, besides the disadvantage of giving the upper districts an undue proportion of light at the expense of the lower. Separate governors for the regulation of pressure at different stages of elevation are not considered necessary, unless the ground has a rise of about thirty feet; and in order to carry out the principle of uniform pressure to the utmost advantage, there ought to be as many governors as the quotient of the whole elevation in feet divided by thirty. Every gas-work for lighting a town should have at least one governor, to regulate the pressure of gas passing from the gas-holders into the first main. Many towns in flat situations, which have no elevations much exceeding thirty feet, will require only this one, but in other very hilly towns it would be advantageous to have several smaller governors to regulate the pressure for their different levels.

The governor is merely a miniature single-lift gasholder—shown at R, Fig. 94—suspended from the centre, and furnished with an inlet and outlet pipe, the former having a conical piston suspended in it —Fig. 101—which regulates the admission of the gas in the reverse ratio of its pressure. The lifting part is usually a cylinder of very thin sheet-iron, about five times the diameter of the inlet pipe, so as to give plenty of room for the two pipes to stand inside, and leave a space above for the gas to occupy in passing through the governor. The tank is made of cast-iron plates, of a circular form, usually somewhat less in depth than the diameter, and with the capacity of about two cubic feet for every ten thousand feet of gas required to be passed through in twenty-four hours. Thus, a tank about five feet four inches diameter, and four feet six inches deep, will be sufficient for a governor to pass three hundred thousand cubic feet of gas in twenty-four hours. The lifting part or invert cylinder, R, is about the same depth, and about four inches less in diameter. The inlet pipe, which may be about twelve inches or less in diameter, is provided with a flange at the base, and is screwed to the bottom of the tank, where it passes up in the centre through the water contained in the tank. The top of the inlet pipe is also provided with a flange, on which is screwed an annular casting, which contracts the opening to eight inches. In this inlet pipe is suspended a solid cone of iron, varying from six to fifteen inches in diameter at base, and about two at top. This cone is suspended from and attached to the centre of the roof of the lifting cylinder, R, so that the cylinder and cone rise and fall together. To the centre of the roof, on the outside, is attached a chain passing over a pulley, which sustains, at its other extremity, a weight so adjusted as nearly to balance the weight of the conical piston. It is evident that, when the pressure of gas is very small, the cone descends, and allows a large escape from the top of the inlet pipe; and, on the other hand, when the pressure increases, the cone will rise and contract the openings, so as to cause a diminished quantity of gas to enter. Of course the perfection of this action depends on an accurate adjustment of the weight, and when once this is effected, the regulation of pressure is so perfect as to leave nothing to be desired. The gas, when once admitted into the space above the inlet pipe, finds no impediment to its progress, and passes off by the outlet pipe without further hindrance. The cone is usually made of cast-iron, and is turned true in the lathe. The orifice at the top of the inlet pipe is also bored true, and of a conical form, so as to fit the base of the cone. The regulation of the weight and counterbalancing chain is very simple, and needs no further description.—*Hughes.*

The House-Meter.—This meter, by which the consumer registers his consumption, consists of one hollow drum or cylinder, revolving about a horizontal axis within another hollow drum or cylinder, the inner drum being divided into compartments for measuring the gas, and revolving in water which occupies the lower part of the outer cylinder to a height above the axis, about which the inner drum revolves. The details of the construction may be varied, but the wet gas meters have this common feature, that the gas is measured in the compartments of a drum, which compartments are occupied successively by gas and water, the drum being made to revolve by the pressure or elastic force of the gas acting on the compartments of the drum in succession. The revolutions of the drum being registered by suitable apparatus, the quantity of gas which has passed through the meter, by so filling the compartments in succession, will be accurately measured.

Fig. 116.



In Fig. 116, the outer circle represents the outer case or drum of the meter, within which a drum divided into compartments, A, B, C, D, revolves about an horizontal axis, *e*. The gas to be measured is brought into the meter by a pipe passing horizontally in the direction of the axis of the inner and outer cylinder, and turned up at the end, so that its orifice, *a*, may stand above the water level, *f*, *g*. The four compartments, A, B, C, D, are similar in every respect, each having an inlet, *b*, by which the gas enters the compartment, and an outlet, *c*, by which it passes out of the compartment into the upper part of the outer case, whence it may pass by a pipe, *k*, in any convenient direction. The gas being admitted into the meter, will pass the inlet, *b*, into the part of the compartment, D, which is just rising out of the water; the gas presses equally on the surface of the water and on the side, *h*, of the compartment, D; the effect of this pressure on the side, *h*, is to cause the inner drum to revolve, whereby the compartment, D, is raised more and more out of the water, and, as it rises, it fills with gas, until it occupies, by the revolution of the drum, the position in space of the compartment C, as to which it will be observed that the inlet, *b*, has just dipped below the surface of the water, and the outlet, *c*, is just coming to the surface of the water. The outlet, *c*, having risen above the surface, the gas will escape into the upper portion of the outer case. As the gas passes out of a compartment in the situation of C, by the outlet, *c*, water will enter by the inlet, *b*, and as the drum revolves the compartment D having occupied the position in space of C and B, comes into the position A, when it is entirely emptied of gas and filled with water, until, by further revolution of the drum, the compartment having come again into the position of D begins to fill with gas, as already described. That which has been described for one compartment takes place for the other three, and it will be seen that there will always be two compartments discharging their gas into the outer case above the water level, one compartment filling with gas, and as it fills causing the inner drum to revolve, and one compartment full of water. The motive power causing the inner drum to revolve, is the pressure of the gas in the mains as transmitted from the gas-holder at the gas works, and the quantity of gas will be ascertained from the number of compartments which have filled and emptied, that is, from the number of revolutions of the inner drum, which are registered by a train of wheel work and a dial plate in the usual manner. The gas so measured and passed through the meter is conveyed to the lights by a pipe communicating in any convenient manner with the outer case, and the action of the meter is suspended when the gas does not pass away. It will be observed that the quantity of gas measured will be affected by the height of the water in the meter, the portion of the compartment which is occupied by gas being greater or less, according to the level of the water, whereas the inner drum will revolve whatever the height of the water, within certain limits. If the water rises above the top of the supply pipe, *a*, the entrance of the gas may be stopped altogether, and if it sinks so low that the orifices *b* and *c* are not sealed or closed and opened simultaneously, the gas may pass through the meter without causing the inner drum to revolve. Hence every gas meter is or ought to be adjusted to a certain water level; if the water rise above this level each compartment will measure too little gas, and since the number of revolutions is the same whatever the available space in the compartment for holding gas, the consumer will be defrauded; on the other hand, if the water sink below this level, since the available space in each compartment is larger than was calculated on, the manufacturer will be defrauded. Various causes are in operation to occasion a variation in the water level, and the necessity of preserving it has given rise to several ingenious contrivances for discharging any excess or supplying any deficiency of water.

All this may be further illustrated by Figs. 117, 118, and 119. In Fig. 117, the direction of the gas is marked by arrows. The box *a*, in which the inlet pipe valve is contained, is soldered tightly, having no communication with the rest of the case, except through the valv the position of which is shown by the arrows: *b* is th inlet pipe projecting above the water line, conveyin the gas into the meter by the bent arm *c*—Figs. 11 and 119—rising above the water between the convex cover and the inlet hoods. *d* is a float attached to th inlet valve, fixed so that when the water falls belo the centre opening the valve will close, and the gas cease to enter the meter. Motion is communicated to the train of wheel-work behind the index from a spiral worm, *u*,—Fig. 118—fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

Fig. 117.

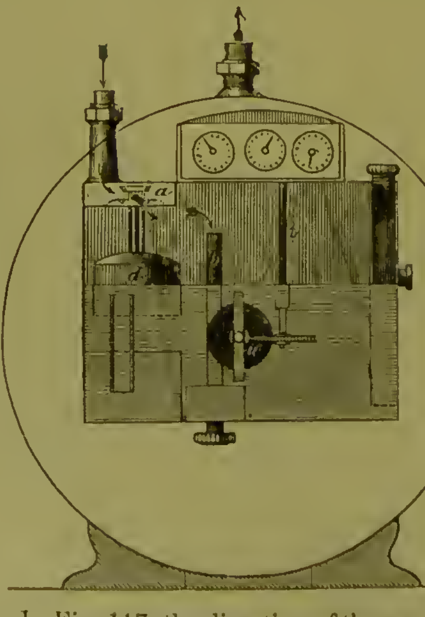


Fig. 118.

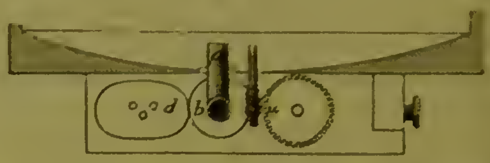
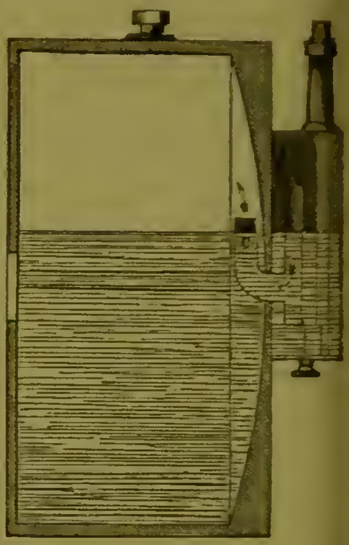


Fig. 119.



There has been much discussion and dissatisfaction in Liverpool of late, with regard to the water meter, parties asserting that although the company had *lowered* the price of gas, still the bills, when they were sent in, were *higher* than they used to be. So many persons came forward and asserted this, that the Editor was applied to by Mr. Whitty of the Liverpool Journal, to know in what way the above could be accomplished. The following question had to be solved: Is it possible by manufacturing inferior gas to compel the meter to register against the consumer?

In the Editor's opinion it is no matter what kind of gas, insoluble in water, is made, *the registration would be the same;* but if *atmospheric air* was passed into the mains and entered the meter in company with *the coal gas*, it would tell against the consumer, *and the light emitted* would be deteriorated. Mr. Whitty remarks in reply to the Editor's statements, that experiments performed at the gas works justified them. It appears by introducing one-tenth of common air into the gas-holder charged with gas, that the meter registers ten per cent. or more against the consumer. Some denied that gas so mixed with air would burn, but the results showed that it does, and had no effect visible to the eye, which is an important fact.

The following table, extracted from a paper containing some experiments by Mr. Barlow, on the comparative value of coals for the manufacture of gas, may be found useful, especially to persons who are compelled to use cannel coal for enriching gas of low illuminating power:—

Name of Coal.	Number of experiments, the average of which is taken.	Produce of one ton of Coal.				Equivalent of one cubic foot of gas in grains sperm.	Consumption of gas per hour to give a light equal to twelve standard candles	Value of the gas from one ton of coals in pounds of sperm.
		Cubic feet of gas.	Pounds of coke.	Pounds of tar.	Pounds of ammoniacal liquor.			
Boghead cannel,	3	13,334	715	733·3	none.	1109·	1·3	2057
Newcastle cannel,	3	9,833	1426	98·3	60·	606·	2·37	851
Wigan cannel—Inec Hall,	3	10,850	1332	218·3	161·6	465·8	3·09	718
Lochgelly cannel,	2	8,331	1245	225·	340·	439·	3·28	522
Mixture of 7-8ths Lochgelly and 1-8th Boghead,	1	9,055	1200	400·	170·	695·	2·07	899
,, 9-10ths Lochgelly and 1-10th Boghead,	2	9,050	1205	335·	290·	600·	2·4	774
,, 11-12ths Lochgelly and 1-12th Boghead,	1	9,750	1240	227·	270·	443·	3·25	617
Pelton main,	4	9,500	1540	112·5	112·5	311·	4·7	422
Mixture of 3-4ths Pelton and 1-4th Boghead,	3	12,800	1366	206·6	116·6	553·	2·6	1009

Mr. BARLOW is of opinion that coals which contain more than thirty per cent. of volatile matter, require a higher temperature for their distillation.

As all the volatile matter afforded by coal is not combustible, it does not necessarily follow that the coal which yields the largest amount of gas is the most valuable, although such is generally the case, as will be seen by the following tables, drawn up by Mr. SAMUEL HUGHES:—

Description of Coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas	Weight of gas in pounds avoirdupois per ton of coal.	Authority.
NEWCASTLE COALS.				
English caking coal,	8,000	·420	257	Dr. Fyfe.
Newcastle coal,	11,648	·675	423	Mr. Joseph Hedley.
Pelaw, Newcastle,	11,424	·444	389	" "
Pelton, do.,	11,424	·437	382	" "
Blenkinsopp, Carlisle,	11,200	·521	447	" "
Newcastle,	8,500	·412	268	London, 1837.
Wallsend, Newcastle,	12,000	·490	550	Quantity made in the revolving web retort —authority, Mr. Clegg.
Pelton,	11,000	·430	363	Author of the Chemistry of Gas-lighting in the *Journal of Gas-lighting*.
Leverson,	10,800	·425	353	
Washington,	10,000	·430	330	
Pelaw,	11,000	·420	355	
New Pelton,	10,500	·415	335	
Dean's Primrose,	10,500	·430	347	
Garesfield,	10,500	·398	321	
Gosforth,	10,000	·402	308	
West Hartley,	10,500	·420	339	
Hasting's Hartley,	10,300	·421	333	
Blenkinsopp,	9,700	·450	335	
Berwick and Craister's Wallsend,	12,507	·470	449	Mr. Clegg,
Pelaw Main,	12,400	·420	399	"
Russell's Wallsend,	12,000	·418	384	"
Ellison's Main,	11,200	·416	357	"
Felling Main,	11,200	·410	351	"
Pearith's Wallsend,	11,147	·410	350	"
Dean's Primrose,	11,120	·410	349	"
Penton Main,	10,987	·420	337	"
Eden Main,	10,400	·400	318	"
Heaton Main,	10,400	·410	326	"
	9,000	—	—	Average production by the Phœnix Gas Company for the year 1848.
PARROT OR CANNEL COALS.				
Yorkshire parrot,	11,000	—	—	Dr. Fyfe.
Wigan cannel,	9,500	·460 to ·520	357	"
Scotch parrot,	9,500	·640	466	"
Ramsay's Newcastle cannel,	9,746	·554 to ·580	423	"
Lochgelly parrot,	9,123	·567	396	"
Lesmahagow cannel—first experiment,	11,681	·540	483	Mr. Wright.
" " second experiment,	9,878	·650	492	"
Ramsay's Newcastle cannel,	9,016	·604	417	"
" " "	9,333	·598	427	John Kay, Manager of Dundee Gas-works.
" " "	9,667	·731	541	Dr. Leeson, Dr. Miller, and Mr. G. H. Palmer.
Lesmahagow cannel,	11,312	·737	638	Mr. Joseph Hedley.
Welsh cannel,	11,424	·737	645	" "
Wigan cannel,	11,200	·606	520	" "
" "	9,500	·580	422	Liverpool New Gas and Coke Company.
Wemyss cannel,	10,976	·670	563	Mr. Wright.
" "	10,192	·691	538	"

Description of Coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in pounds avoirdupois per ton of coal	Authority.
Wigan cannel,	9,408	·478	344	Mr. Wright.
Knightswood cannel,	9,720	·590	439	"
Boghead cannel,	15,000	·752	866	Mr. J. Evans, at Westminster Station of Chartered Gas Company; mean of three experiments.
Lesmahagow,	13,500	·642	666	" " "
"	13,200	·618	627	" " "
Capeldrae cannel,	14,400	·577	638	" " "
Arniston cannel,	12,600	·626	606	" " "
Ramsay cannel,	10,300	·548	433	Mr. J. Evans.
Wemyss cannel,	14,300	·580	637	"
Kirkness cannel,	12,800	·562	552	"
Knightswood cannel,	13,200	·550	558	"
Wigan—Ince Hall—cannel,	11,400	·528	461	"
Pelton cannel,	11,500	·520	459	Mr. Joseph Hedley.
Leverson cannel,	11,600	·523	466	" "
Washington cannel,	10,500	·500	403	" "
Wigan cannel,	14,453	·640	708	Mr. Clegg.
" "	14,267	·610	664	"
Scotch cannel,	14,000	·580	622	"
" "	13,813	·500	529	"
Derbyshire, Welsh, Staffordshire, and other kinds of Coal.				
Derbyshire deep main,	9,400	·424	308	Mr. Wright.
Brymbo two-yard coal,	8,880	·463	315	"
Powell coal—two hundredweight charges every five hours,	10,165	·459	357	"
Powell coal—one and a half hundredweight charges every five hours,	8,250	·470	296	"
Bickerstaff—Liverpool,	11,424	·475	415	Mr. Hedley.
Neath—South Wales,	11,200	·468	401	"
Birmingham Gas Company—lamp coal from West Bromwich,	6,500	·453	226	Birmingham Gas Company Parliamentary Return.
West Bromwich,	6,500	·455	227	Birmingham and Staffordshire Parliamentary Return.
Macclesfield,	6,720	—	—	
Stockport,	7,800	·539	322	Parliamentary Return.
Oldham, Watergate, and Wigan cannel, mixed,	9,500	·534	388	Manchester Parliamentary Return.
Ormskirk, or Wigan slack,	8,200	·462	290	Liverpool Old Company Parliamentary Return.
Low-Moor, mixed with two kinds of slack,	8,000	·420	257	Bradford Parliamentary Return.
Leeds coal,	6,500	·530	263	Leeds Company Parliamentary Return.
Cannel and common coal mixed,	8,000	·466	285	Sheffield Company Parliamentary Return.
Derbyshire soft coal,	7,500	·528	303	Leicester Parliamentary Return.
" "	7,000	·448	240	Derby Parliamentary Return.
" "	7,000	·424	227	Nottingham Parliamentary Return.
Staffordshire.				
South's,	10,933	·398	333	Mr. A. Wright.
Second variety,	10,667	·395	322	"
Third variety,	10,667	·390	318	"
Fourth variety,	9,600	·320	235	"
Forest of Dean,	10,133	·350	271	"
Second variety,	10,133	·360	279	"
Welsh Coal.				
First variety,	10,000	·385	295	"
Second variety,	10,133	·380	295	"

Some practical gas engineers are of opinion that the quantities in the preceding table are larger than are usually obtained in the works. The following table, by Mr. Wright, in which the results of experiments on the distillation of cannel coals are placed in a very practical commercial form, will be found interesting:—

	Name of Coal.						
	Lesmahagow cannel.		Ramsay's Newcastle cannel.	Derbyshire deep main.	Wemyss' cannel.		Wigan cannel.
	Exp. 1. Pounds per ton.	Exp. 2. Pounds per ton.	Pounds per ton.	Pounds per ton.	Exp. 1. Pounds per ton.	Exp. 2. Pounds per ton.	Pounds per ton
Coke,	1091·	1064·	1435·	1335·	1124·5	1188·	1326·0
Gas,	463·	483·5	410·	300·	551·4	528·	338·0
Tar,	594·	603·	295·	219·	224·0	197·	250·0
Ammonia and water,	4·5	4·5	6·72	179·	—	—	—
Loss,	87·5	85·	93·28	207·	340·1	327·	326·0
	2240·	2240·	2240·	2240·	2240·	2240·	2240·
Cubic feet of gas,	11,681	9,878	9,016	9,400	10,976	10.192	9,408
Specific gravity,	0·540	0·650	0·604	0·424	0·670	0·691	0·478
Illuminating power, gas of specific gravity 0·361, being,	—	2·33	2·	0·8	2·47	—	1·5

The annexed tables, by Dr. FYFE, contain, in addition to the quantities of gas afforded by the coals, much valuable information upon the relative illuminating values of the gases, which he arrived at by the chlorine test. When chlorine is added to coal-gas, it forms with the olefiant gas and the vapors of tar oil—with those constituents, therefore, upon which the illuminating power depends—a fluid compound, which separates, and the original volume is consequently diminished. The diminution which the volume of the gas suffers when mixed with chlorine is, therefore, in direct proportion to its illuminating power, and to the value of the gas—to the amount of olefiant gas and tar oil vapors—which it contains:—

Coals.	Cubic feet of gas per ton.	Comparative value of coals per ton by quantity of gas	Specific gravity of gas, air = 1000.	Condensation by chlorine per cent.	Duration by jet, five-inch flame.	Comparative value of gas by chlorine.	Comparative value of gas by durability.	Comparative value of gas by chlorine and durability.	Comparative value of coals per ton, taking quantity of gas condensed by chlorine and durability into account.
ENGLISH CANNEL:—					M. S.				
Yorkshire,	11,500	1·28	·451	7·66	45·	0·85	0·92	0·78	1·00
SCOTCH CANNELS:—									
Knightswood,	8,960	1·00	·557	·9	48·	1·00	1·00	1·00	1·00
Lochgelly,	9,123	1·01	·567	14·5	65·30	1·66	1·36	1·95	1·11
Marq. Lothian,	10,000	1·11	·556	13·	60·	1·44	1·25	1·80	2·00
Torryburn,	11,200	1·24	·624	13·	57·30	1·44	1·19	1·71	2·13
Monkland,	10,190	1·13	·667	16·	67·	1·77	1·4	2·01	2·29
Arniston,	10,640	1·18	·637	17·5	68·30	1·94	1·41	2·03	2·41
Wemyss,	10,080	1·12	·642	19·5	75·	2·16	1·56	2·24	2·54
Kirkness,	9,620	1·07	·711	20·75	80·18	2·30	1·67	2·40	2·58

This table exhibits the quantity of gas afforded from a ton of each of the coals; the specific gravity of the gas; the amount of condensible matter by chlorine; the durability of the gas when burned by a single jet with a five-inch flame; the comparative value of the gas for affording light, as shown by the chlorine test, by the durability, and by these taken together, which, when test is had recourse to, is the proper method to follow. It shows also the comparative value of the coals for the purpose of illumination by the combustion of their gases, as proved by the quantity of gas afforded by each, and also by the quantity and quality taken together:—

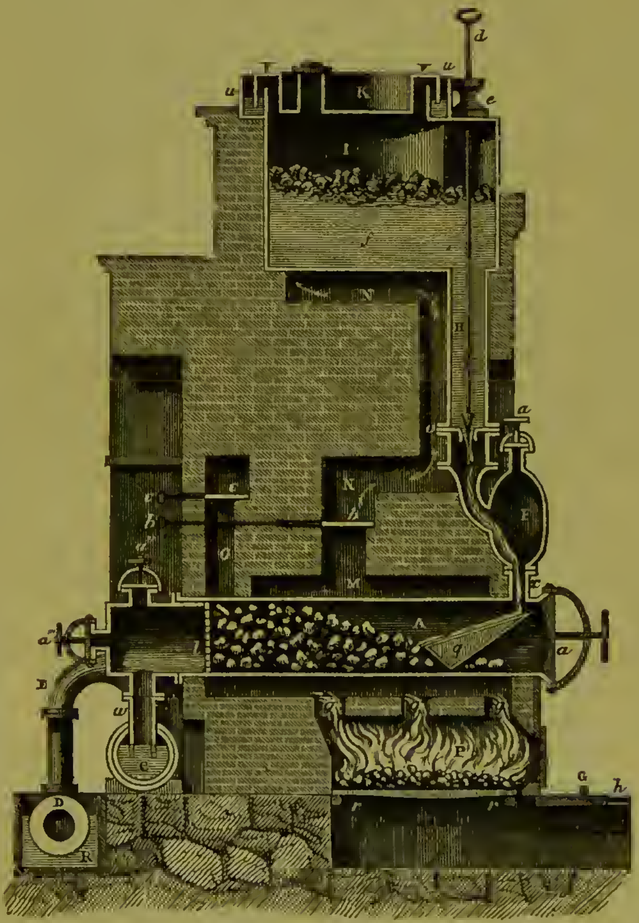
Coals.	Cubic feet of gas per ton.	Specific gravity of gas, air = 1000.	Condensation by chlorine, per cent.	Durability by jet five-inch flame.	Illuminating power, one foot sperm. candles = 120 grains per hour.	Value of one foot in grains sperm.	Comparative value of one foot in grains sperm.	Value of one ton of coals in pounds of sperm.	Comparative value of coals.	Pounds of coke per ton of coal.	Fixed carbon per cent. in coal.	Ashes per cent. in coal.	Pounds of sulphur per ton of coal.
ENGLISH CORING:—				M. S.									
Pelton,	9,746	555	6·5	50·40	3·125	382·2	1·	532·	1·	1,563	—	—	—
ENGLISH CANNEL:—													
Ramsay's Newcastle,	9,692	625	13·25	60·40	3·33	399·6	1·04	553·	1·04	1,520	—	—	—
Wigan,	12,010	566	9·9	52·5	3·04	365·4	0·95	627·4	1·17	1,360	55·	7·1	—
SCOTCH CANNEL:—													
Donibristle,	9,923	593	9·	51·5	7·51	901·2	2·35	1277·5	2·4	1,220	49·22	4·28	8·5
Lesmahagow,	10,176	669	17·	60·	8·77	1058·8	2·75	1539·5	2·87	1,360	42·44	4·	—
Capeldrae—one,	11,500	644	18·	65·25	8·312	997·4	2·61	1638·7	3·08	9.999	33·2	7·7	7·7
Capeldrae—two,	9,670	650	17·8	73·37	10·01	1201·2	3·24	1670·3	3·18	1,256	23·9	24·5	
Boghead,	15,426	726	23·37	84·44	10·38	1245·6	3·25	2755·6	4·3	760	9·25	21·7	8·

Having given a full account of the manufacture of coal gas—the Liverpool works, as stated before, being taken as the standard—it will now be desirable to enter upon the fabrication of this compound from other sources, such as oil, resin, *et cetera;* and, in doing so, the Editor will draw largely from the admirable work of Drs. RICHARDSON and RONALDS upon *Fuel,* which has just been published. It contains concise and exact information upon the several heads that will now be discussed.

Resin Gas.—Resin could be distilled in the oil-gas apparatus, if it were fluid at common temperatures; but such not being the case, it requires to be liquified by heat, or some solvent, before it is allowed to pass into the retort. Coal-tar naptha is often used to dissolve the resin, or the oil which results from its own distillation. When the latter is employed, the flame from the furnace, before escaping into the chimney, is allowed to play upon the reservoir of resin. As the resin melts, it trickles through a sieve into a second division of the vessel, leaving the impurities and the solid portion behind, where it is mixed with an equal part of the resin-oil. Thus a solution which will no longer solidify is obtained, and with it the retort is supplied, as with oil in the former case. When the gas, either from resin or oil, has parted with its condensable vapors in the coolers, it is in a fit state for consumption, no further purification being required.

According to Ronalds and Richardson, one of the best arrangements of apparatus for making resin gas, and which has stood the test of practice, is that which has been extensively carried out by Chaussenot, and is shown in Fig. 120. The resin is here melted without any additional solvent, and the oil or tar collected and disposed of as a secondary product. The draught to the fire-place, P, is regulated through the ash-pit by means of the plate, G, which can be moved horizontally backwards and forwards in the groove, *h*. The air traversing from below through the grate and fuel, *r r*, creates a powerful flame, which passing, in the first instance, through the apertures, *g g g*, in the roof, plays round the retort, A, in the space, M, and then, before reaching the chimney, heats the vessel, I, containing the resin, by means of the flue, N N. If this vessel requires filling, the fire is shut off from N by the damper, *b*, and is allowed free egress at the aperture, O, by drawing back the damper, *c*. Both the dampers are worked by iron rings and rods from without. In this apparatus it is not necessary to dissolve the resin in tar-oil, because the vessel, I, in which the resin is melted, and the conducting tube, H, being constantly surrounded by hot air, no solidification of the melting resin at the bottom, *f*, can take place. Combustible gases are generated by merely melting the resin, which may possibly endanger the whole apparatus. To avoid such contingencies, the edge of the resin cistern, I, is furnished with a groove filled with water, *u u*, into which the lid, K, dips at *v v*, and is consequently secured by a water-valve. By means of an aperture in the lid, the vapors can be conducted into the chimney or under the grate. The melted resin flows consecutively through H, F, and *x*, into the retort, A. Between F and H is a plate, *o*, with a funnel-shaped aperture in the middle, in which the conical end of the rod, *d*, is movable. If this is raised through the stuffing-box, *e*, a more abundant supply of melted resin is furnished to the retort; if it is pushed down, the stream diminishes, or the flow ceases entirely. The resin flowing from *x* is carried to that part of the retort containing the coke, by means of the inclined plate, *q*. The coke is prevented falling back in the retort by the grating, *l*, the gas escapes through a descending pipe, *w*, to the tar-cistern, C, and from thence through E to the coolers, D, which are immersed in water in a long trough, R. C is nearly always filled with tar, that the mouth of *w* may remain immersed; this, therefore, dips into C, whilst the gas-pipe, E, behind the sectional level in the drawing, only just passes through the material of the main, C. Apertures are constructed in several places, at *a*, *a'*, *a''*, and *a'''*, by which the apparatus may be cleaned at intervals; these are firmly closed during the process of distillation, by flat plates of iron firmly screwed on, by means of iron brackets, similar to that used for closing the mouth of the retort *a*. Distillation goes on continually in this apparatus, until the deposition of carbon renders a renewal of the coke necessary.

Fig. 120.



Resin contains ten equivalents of carbon, seven of hydrogen, and one equivalent of oxygen. Its atomic weight is, therefore, seventy-five. Supposing the whole of the hydrogen to unite with the quantity of carbon required to form olefiant gas of specific gravity nine hundred and seventy six, the utmost that could be produced from an atom of resin would be forty-nine parts out of seventy-five, or about two-thirds of its weight, accompanied by some carbonic oxide and carbonic acid. If any of the hydrogen is evolved uncombined, or in the form of light carbide of hydrogen, a proportionate quantity of carbon must escape conversion into gas, and hence the loss which must always attend the distillation of resin, even supposing that none of it were distilled unchanged, or converted into resin-oil.

Dr. Fyfe obtained the following quantities of gas by distilling resin at different temperatures, of which he also ascertained the relative specific gravities and illuminating power:—

Temperature of distillation.	Quantity of gas per pound of resin	Specific gravity of gas.	Per centage of carbonic acid.	Durability or quantity consumed per hour in jet 1·33 inch diameter, and five inch flame.	In Argand burner consuming five feet per hour, illuminating power was equal to candles.	Resin not converted into gas; fraction of quantity distilled.
	Cubic feet.			Cubic feet.	Per cubic foot.	
Heat employed for coal-gas, ..	10·	640	10	1·2	2·45	One-half.
Dull red-heat, ...	6·2	657	6	1·25	2·27	Two-thirds.
Somewhat above dull red-heat,	8·42	419	8	1·43	—	One-half.
,, ,,	9·	613	—	—	—	One-half.
In White's retort without water-gas, ...	8·8	57	—	1·12	2·	Three-fifths.

He considers, therefore, that the quantity of gas that can be produced from resin in practice will not exceed eight or nine cubic feet per pound, that is, about one thousand cubic feet per hundredweight; that the gas, after being purified, will be of specific gravity not much beyond six hundred; the condensation by chlorine not much beyond eight or nine per cent.; a cubic foot of gas not giving more than the light of from two and a half to three candles.

Hydrocarbon, or Water-gas.—It is well known that water passed in the form of steam over red-hot iron, is decomposed; its hydrogen being liberated in the form of gas mixed with a little carbide of hydrogen from the carbon of the iron, while the metal becomes converted into oxide. If coke or charcoal be substituted for iron in this operation, hydrogen, carbonic oxide, and carbonic acid gases are produced in variable quantities, according to the temperature employed; carbide of hydrogen, according to Dr. Fyfe, being only present in very small quantity.

Gas from Animal Matter.—In the distillation of animal matters, bones, flesh, *et cetera*, which has long been practised for the production of bone-charcoal and bone-black, a tar containing Dippel's animal oil, and gases, are generated. The illuminating power of the latter has recently attracted the attention of manufacturers. Seguin in particular has carried on the process on a large scale, making use of the gases. When the flesh of dead animals, which contains sixty per cent. of water, is employed, the latter must be removed by exsiccation before the material is placed in the retorts, which are kept at a cherry-red heat. The sulphur—a constituent of albumen, fibrin, *et cetera*—is chiefly found in the gas combined with carbon, and the nitrogen of the flesh as carbonate of ammonia. After being properly cooled, the gas is first passed through a solution of chloride of calcium, where carbonate of lime and chloride of ammonium are formed, and thence through pipes containing lumps of sulphur, which condense the bisulphide of carbon to the liquid state. The latter would be converted in the flame into sulphurous acid and carbonic oxide.

Gas from Wood and Turf.—Wood and turf are not well adapted for yielding gas for the purposes of illumination, but where coal cannot be had, or only at a very high price, they may be advantageously resorted to as a means for illumination, as may be testified by many communities at a distance from bituminous coal, which are in the enjoyment of gas-light obtained from one or other of these sources. The illuminating power of the gas liberated from these by distillation, is, it is true, inferior to coal gas; but it may be rendered even superior to the latter, by transmitting it through vessels containing naphtha or oil of turpentine, or retorts which are charged with charcoal kept incandescent by the application of external heat. These facts are entirely of recent discovery. Dr. Pettenkofer of Munich claims the honor of being the first to prepare gas suitable for illuminating towns and dwellings, *et cetera*, from wood; and his invention is gaining more attention daily in Germany, where the consumption of wood-gas is already very large. The manufacture of gas from wood is stated to offer many facilities and advantages which are not experienced in the distillation of coal; among these is that of expedition, the gas being freely evolved from the wood, and allowing the charging of the retorts to take place every hour and a half. The tar from the wood distillations is more abundant, and the charcoal is much more valuable than the coke. Further, in coal gas-works the retorts are rapidly worn out, owing to several causes, such as the superior temperature caused by the sulphur in the coal; but it is not so in the manufacture in question, for the heat of distillation is considerably lower, and sulphur is absent. In Munich, where wood gas is used, the usual ᴜ-shaped retorts are employed; they are charged with ninety pounds of wood, from which as much gas is obtained as will suffice for two hundred and eighty burners. Immediately on introducing the dried wood into the red-hot retort, gas is evolved, which passes off through an arrangement of pipes, mains, scrubbers, and dry lime purifiers in the usual way. The charcoal, when drawn out, is cooled with wet sand. Liebig and Steinheil give the illuminating power of this gas as *six*, coal-gas being estimated at *five*.

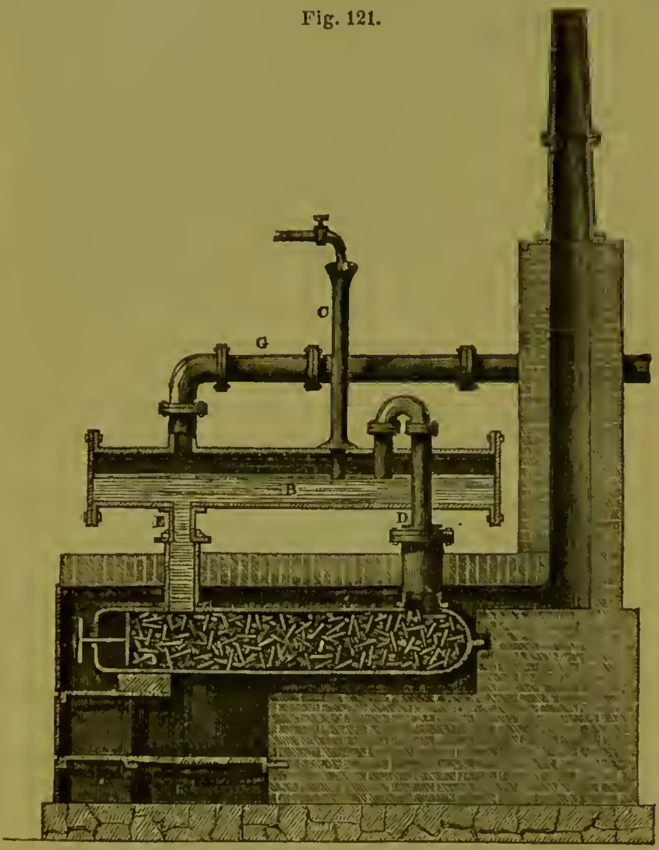
Oil-Gas.—It appears, at first sight, both inexpedient and superfluous to distil oil for the production of gas, when it is considered that oil can be burnt in lamps without any further preparation, while it loses carbon by deposition in the retorts. Purified lamp oil is consequently never used; but gas can be prepared from impure oils, train-oil, or refuse fat, with as much ease as from the purer kind. The manufacture of oil-gas is, therefore, under certain circumstances, an admirable means of using up such materials for the production of light as could not otherwise be employed, or could only be applied to the lowest uses.

In 1815, Mr. J. Taylor obtained a patent in this country for the manufacture of gas from refuse fatty matters, and his plans were carried out at the gas-works at Paris, Liverpool, Bristol, and Hull; but the cost of raw material not being able to compete with that of coal, the oil-gas manufacture has been discontinued in this country.

The experiments of Henry, which extend also to this part of the subject, show at once the plan that must be adopted upon a large scale. The following account of the results obtained, and the process of the manufacture, is given in Knapp's *Technology:*—

It appears that the oil-gas is superior to that obtained from coal, as is also shown by its density, and that the produce, dependent chiefly upon the temperature, is of the best quality when obtained at a low red heat. This temperature suffices to convert the oil into gas, but is not sufficiently high to decarbonize the gas to any great extent. The apparatus for obtaining gas by the distillation of oil is represented in Fig. 121. The retort, A, is filled with bricks, or lumps of coke, which very materially increase the red-hot surface, and promote the evolution of gas, shortening the time which the gas already produced has to remain in the red-hot vessel. The second cylinder, B, serves both as reservoir and hydraulic main, A and B being connected in two places, D and E. Oil flows from a large cistern above the apparatus in a constant stream through the tube C into B, which is thus kept filled up to a certain level. From B, the oil descends through E to A, where it is converted into gas and tar, both of which are volatilized, and return through D to B. The pipe, D, is bent, and its open end delivers just below the fluid level in B, so that the vapors of the decomposed oil must constantly pass through the reservoir of oil, and deposit their tar. The retort, A, is therefore constantly supplied, not only with oil, but with a mixture of oil and tar, in such a manner that all the condensed products return to the retort together with a fresh quantity of oil, until they are completely converted into gas. If the operation be conducted in a long tube, inclined at the hinder part, while the front is kept cool, hardly any tar is produced. The gas which collects above the oil in B passes on through the tube, G. The objections to the use of metallic vessels in distilling coal, are not applicable to the distillation of oils; and cast-iron vessels are, therefore, always employed, and heated over a furnace constructed in the usual manner. According to trustworthy statements, one cubic foot, or about four gallons of oil, produce six hundred to seven hundred cubic feet of gas, which is equivalent to from ninety to ninety-six per cent. of the weight of the oil; the remainder—excepting some unavoidable loss—consists of carbon, which is deposited upon the coke or bricks. According to Dr. FYFE, a gallon of oil seldom yields one hundred cubic feet of gas of good quality, on a large scale. That made at Leith, and in private gas-works at Edinburgh, had a specific gravity of from six hundred and forty to seven hundred and ten, containing matter condensable by chlorine. In this manufacture, about one half only of the oil is converted into gas. The production of oil-gas is a continuous process, and thus differs from the distillation of coal. The retorts only require opening now and then, for the removal of the deposit of plumbago. Vapors of the same composition and properties are found in oil and coal gas. Thus, according to HESS, all the volatile empyreumatic oils, which occur mixed with each other in the tar from oil, have the same composition per cent. as olefiant gas. In the oil-gas made in England, and submitted to a presure of twenty or thirty atmospheres, in order to render it portable, FARADAY observed that seven thousand five hundred volumes of gas were converted into one volume of fluid; and among the oily bodies, of which the liquid is composed, and which contain from eighty to ninety per cent. of carbon, this chemist was enabled to study some in an isolated state, as triyl—$C_2 H_8$ ditriyl—$C_2 H_4$—and a third hydrocarbon—$C_2 H_8$.—*Knapp.*

Fig. 121.



Gas from Soap-Water.—A favorable idea of the practical value of chemical knowledge is afforded by the process carried out at the works of HOUZEAU-MUIRON at Rheims, where very good gas and a handsome profit are obtained from a substance which had previously been a source of expense to the manufacturer to get rid of it. This refuse is the soap-water in which woollen stuffs have been freed from fat. Besides the unchanged fat with which the goods are charged as they come from the loom, the soap-water contains a solution of oleate and stearate of soda, and compounds of the samo acids with lime in suspended flakes. and. lastly, animal matter extracted from the wool. From all parts of the town the soap-water is collected, and brought to the reservoirs of the works, where three hundredweight at a time are treated with two per cent. of sulphuric acid, or twice as much hydrochloric acid, mixed with an equal quantity of water. After the lapse of twelve or eighteen hours, the water is found to contain GLAUBER'S salt or sulphate of soda in solution, a little gypsum being formed at the same time, while an impure grey fatty matter rises to the surface. This consists of the fatty acids, oil, and animal matter mixed with water, the greater part of which having already been mechanically separated. the remainder is removed by melting the fat in a copper vessel, and ultimately drawing it off into a second boiler containing some sulphuric acid, for clarification. The filtration which follows affords a clear oil, and this gives with crude soda—containing sulphide of sodium—a very tolerable soap, whilst sulphide of iron separates, leaving a black solid residue containing much fat for distillation in the retorts. The process of distillation is similar to that practised with resin; the tar produced the first day is used on the morrow to dissolve and liquify the solid residue. The soap-water is obtained at the rate of ninepence for every thirty gallons.—*Knapp.*

Hydrocarbon Gas from Boghead Cannel.—The following interesting account of hydrocarbon gas from Boghead cannel, is adapted from an article in the *Journal of Gas-lighting*, from the pen of Dr. FRANKLAND of Manchester:—In the summer of 1851, this excellent chemist made an extensive series of experiments on the manufacture of hydrocarbon gas from cannel coals, in which the results obtained by WHITE'S process were compared with those yielded by the usual method of gas-making. The experiments were made on a manufacturing scale, the cannels being worked in one hundredweight charges, in diaphragm retorts of the D shape, six feet long, one foot six inches high, and one foot wide. The condensing and purifying apparatus was of the ordinary description, and the gas was passed through a station-meter immediately previous to its entrance into the holder, and at a temperature rather below than above that of the atmosphere.

Instead of receiving the whole of the gas in a large holder, and then experimenting upon the total quantity, FRANKLAND preferred, for certain reasons connected with the apparatus then at his disposal, to receive a portion only of the gas in a smaller holder, which was placed close to the meter, and received its supply through a very short three-fourths of an inch pipe from the main entering the meter. This small holder was capable of containing eighty cubic feet, and the flow of gas into it was continuous throughout the whole process, and accurately regulated by a graduated stopcock, so as to allow the admission of a certain per centage throughout the entire working; for instance, if a ten per cent. sample was being taken, ten feet entered this holder during the time that ninety feet passed through the large meter. He had previously satisfied himself that, by attending to certain precautions mentioned below, this method furnished a perfectly fair sample of the total gas produced.

The results proved, in favor of the hydrocarbon process, a gain of from 45·8 to 290·6 per cent. in quantity of gas, and from 11·2 to 108·6 per cent. in total illuminating power, according to the quality of the cannel used. This gain in the total quantity of light yielded by a given weight of cannel, was also very remarkably corroborated by the analytical estimation of the value of the illuminating hydrocarbons in each gas, as is seen from the following summary:—

	Boghead.		Lesmahagow.	Methel.	Wigan, Incehall.	Balcarras.	Ramsay's Cannel.
	1st Exp.	2nd Exp.					
Per centage gain in illuminating power by hydrocarbon process,	88·4	82·4	82·8	108·6	33·9	42·4	11·2
Per centage gain in hydrocarbons expressed in their equivalents of olefiant gas,	83·9	..	85·1	109·2	34·0	..	11·3
Per centage gain in quantity of gas,	188·2	290·6	174·8	176·2	47·9	48·5	45·8

Subsequently, Dr. FYFE also made an extended series of experiments on the same subject; confining his attention, however, to the Boghead cannel, which, he justly remarks, is best fitted for testing the value of the hydrocarbon process. His results differ most widely from FRANKLAND's, exhibiting invariably a loss of light—sometimes small, at other times enormously great—by the application of the hydrocarbon process.

Dr. FYFE's experiments were conducted upon a very small scale—small D-shaped retorts, two feet six inches long, and nine inches wide, being used, whilst the largest charge of cannel was seven pounds, and even still less quantities were frequently employed. They further differed from FRANKLAND's trials in the whole of the gas being simultaneously received in two holders, so that the subsequent experiments upon it were conducted upon the total quantity of gas produced; whilst, in Dr. FYFE's trials, a per centage only of the gas was received and submitted to experiment. To this latter circumstance mainly, Dr. FYFE ascribes the discrepancy in the results.

For some months after the publication of Dr. FYFE's trials, Dr. FRANKLAND was residing on the Continent; and, for a long period after his return, the want of a suitable apparatus, and the little time at his disposal for such matters, prevented a repetition of the experiments upon Boghead cannel, in order to determine the accuracy or fallacy of former conclusions.

The appearance of another article, however, on the same subject, by Dr. FYFE, in the *Journal of Gaslighting*, for March 1854, confirmatory of his previous results, determined Dr. FRANKLAND at once to institute new experiments, with an apparatus in which the total quantity of gas could be operated upon.

The apparatus employed consisted of a cannel retort of the same size as that used in former experiments, surrounded by four water retorts, each of the same length as the cannel retorts, and nine inches in diameter, furnished with a diaphragm in the usual manner. The gas passed from the retorts through the hydraulic tubular condenser, and small wet and dry lime purifiers, to a station-meter, and thence to the holder, where the whole quantity produced in each case was received.

Although two hours were considered amply sufficient for complete intermixture and diffusion of the gases in such a holder, yet an interval of twenty-four hours was in each case allowed to elapse before the gas was submitted to the photometrical experiments. In thus using a large holder, it is indispensable that the gas for the illuminating room should be drawn directly from the water itself, and not from the large outlet-pipe, the unknown contents of which would, in many cases, supply a burner for several hours. This was effected by attaching a flexible tube to an aperture in the crown of the holder, and then conducting the gas to the illuminating room by a half-inch iron pipe. In this manner, a fair sample of the gas in the holder was secured. In all the experiments, the modification of BUNSEN's photometer, by Messrs. CHURCH and MANN, was employed. The gas was consumed in fish-tail and Winfield burners; and, in every instance, the determination was made when the gas appeared to be burning to the best advantage. The numbers obtained were, as usual, corrected to the one hundred and twenty grain candle standard.

Having previously ascertained that Boghead cannel, when distilled alone, yields considerably higher results in small quantities, and being desirous of placing the cannel in the best possible position for a comparison.

only half a hundredweight was used for each experiment, in place of one hundredweight, as employed in previous trials. In making the hydrocarbon Boghead gas, the evolution of water gas was so managed, that the mixture of gases generated throughout the entire working was maintained at a nearly uniform illuminating power. To do this, the generation of water gas must at first be very rapid, and should nearly cease at the end of the second hour. The heat was a good bright red; and, in the trial with Boghead alone, it was slightly higher than in that with Boghead and water.

The following results were obtained:—

I.—BOGHEAD WITHOUT WATER GAS.

Cannel used, ... Fifty-six pounds.
Gas produced, ... Three hundred and sixty-four cubic feet.
Time occupied, ... Two hours and forty-five minutes.
Gas per ton, ... Fourteen thousand five hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1.	Three cubic feet per hour, fish-tail No. 2.	Four cubic feet per hour, fish-tail No. 3.	Five cubic feet per hour, Winfield's burner.
Candles.	Candles.	Candles.	Candles.
14·7	25·5	36·4	48·9

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles	Candles	Candles	Candles
7·35	8·5	9·1	9·78

Illuminating power of total gas, when burnt at the rate of three cubic feet per hour, = 309·4 sperm candles, each sperm candle burning ten hours, at the rate of one hundred and twenty grains per hour.

II.—BOGHEAD WITH WATER GAS.

Cannel used, ... Fifty-six pounds.
Gas produced, ... Nine hundred and four cubic feet.
Time occupied, ... Two hours and forty-five minutes.
Gas per ton, ... Thirty-six thousand one hundred and sixty cubic feet.

ILLUMINATING POWER OF GAS.

Two cubic feet per hour, fish-tail No. 1.	Three cubic feet per hour, fish-tail No. 2.	Four cubic feet per hour, fish-tail No. 3.	Six cubic feet per hour, Winfield's burner.
Candles.	Candles.	Candles.	Candles.
11·1	1·90	26·9	48·1

ILLUMINATING POWER OF ONE CUBIC FOOT OF GAS.

Candles.	Candles.	Candles.	Candles.
5·35	6·33	6·72	8·0

Illuminating power of total gas, when burnt at the rate of three feet per hour, = 572·5 candles. Hence, gain in illuminating power by employment of water gas, per ton, = 10,524 candles; 85·0 per cent. Gain in quantity of gas, = 21,[illegible] cubic feet; 175·9 per cent.

These results, therefore, most satisfactorily confirm those obtained in former experiments, *videlicet*:—

	Per Ton. 1st Experiment.	Per Ton. 2d Experiment.	Per Cent. 1st Experiment.	Per Cent. 2d Experiment.
Gain in illuminating power by employment of water gas,	10,028 candles.	9,348 candles.	88·4	82·4
Gain in quantity of gas,	24,920 cubic feet.	38,480 cubic feet.	188·2	290·6

Thus showing that experiments, in which a certain per centage only of the total gas generated is operated upon, are worthy of full reliance if conducted with the necessary precautions; but, in order that the results may be received with the same confidence, FRANKLAND admits that this method requires more faith in the manipulatory skill of the operator than the other; for, as Dr. FYFE has shown, it is easy to commit very serious errors if the necessary precautions be not attended to. The essentials to accuracy are—first, that the tube supplying the small holder from the main should be as short and narrow as practicable; secondly, the gas should be admitted into the small holder *continuously* throughout the entire working, and not in isolated portions at stated periods; and, thirdly, the sample thus taken should not bear too small a proportion to the total quantity of gas generated. In FRANKLAND'S former experiments all these conditions were secured; but in the trial quoted by Dr. FYFE, in which the sample collected in the small holder was thirty-three per cent. worse than it ought to have been, they were disregarded. In Dr. FYFE'S experiments, the capacity of the inlet-pipe was one hundred and thirty-two cubic inches, the gas was received in isolated portions at stated periods, and the sample thus collected bore a relation to the total gas of only 1 : 500. In FRANKLAND'S experiments, the contents of the inlet-pipe were only eighty-three cubic inches; the sample was collected continuously, and in the three experiments on Boghead cannel, it bore relation to the total gas:—

First Experiment, ...	1 : 8·3
Second Experiment, ...	1 : 23·8
Third Experiment, ...	1 : 32·3

These considerations clearly point to the causes of the discrepancy observed by Dr. FYFE in his small per centage sample; and as the results of FRANKLAND'S second series of experiments, made with all the precaution which Dr. FYFE considers necessary to accuracy, coincide closely, as seen above, with those he already published,—the actual gain of light per ton, ten thousand five hundred and twenty-four sperm candles, being somewhat greater than the mean of the first series, nine thousand six hundred and eighty-eight, and the per centage gain eighty-five,—it now only remains to show the cause of the discordance between Dr. FYFE'S experiments and his—the one assigned by Dr. FYFE, viz., the use of a per centage sample, being completely disproved.

In pointing out what FRANKLAND conceives to be the true cause of the discordance, attention will principally be confined to Dr. FYFE'S last experiments, in which he used retorts of the customary size; because FRANKLAND is convinced that no results obtained with such a small apparatus, and such minute charges of cannel as those used in his first experiments, can be relied upon for comparison with experiments on a manufacturing scale. He feels also less reluctance in leaving these experiments out of consideration, since Dr. FYFE himself admits, to a certain extent, that they were made upon too small a scale to be depended upon. For the hydrocarbon process especially, retorts of such small *longitudinal* dimensions are peculiarly unfitted; because the amount of carbonic acid generated in the water retort is greatly augmented by diminishing the length of charcoal surface over which the water gas has to travel, and, for the same reason, a great excess of steam is also very liable to pass into the coal retorts, thus damaging the luminiferous constituents there generated. In addition to this cause of error, the experiments in question must have been much vitiated by the rapid carbonization of the very small quantity of cannel used, nearly the whole of the gas from which would certainly be expelled in thirty minutes—a length of time far too short for the generation of the requisite quantity of water gas from one small retort.

In Dr. FYFE's last experiments, he used two retorts of a large size, one containing the charcoal or coke by which the water was decomposed, the other the coal, of which two hundredweight were used in each charge. Two charges were worked off, both with water gas, and the gaseous products received in a large holder. The average of these trials was twenty-seven thousand cubic feet per ton, yielding light equal to 2830·15 pounds of sperm. Dr. FYFE then compares this result with that which he obtained by working the seven pound charges above alluded to, and thus shows a loss of thirteen per cent. by the hydrocarbon process.

The two principal points, in which the conclusions drawn by Dr. FYFE from these results differ from FRANKLAND's, are—first, his high estimate of the powers of the Boghead cannel distilled alone; and, secondly, the comparatively low results which he obtained by the collateral use of water gas. The first of these points arises, as just mentioned, from reliance being placed upon certain results obtained in small retorts with seven pound charges of cannel, which results differ most widely from those of all other experiments, as also from the previously published report of Dr. FYFE himself.

To determine the influence of small charges in increasing the yield and the illuminating power of the gas from Boghead cannel, FRANKLAND put 2·5 ounces of the same sample as that used in his last experiments in a hand glass tube; it gave 1·88 cubic feet of gas, five feet per hour of which yielded a light equal to 64·5 candles. These numbers are equivalent to fifteen thousand four hundred and eighty-two cubic feet per ton, or 3423·7 pounds of sperm per ton—a result which even exceeds that of Dr. FYFE, and shows how little dependence can be placed in experiments upon small quantities of this cannel.

It is, therefore, greatly to be regretted, that Dr. FYFE did not, at the time of making his last experiment at Leith, try a corresponding one with Boghead cannel alone in the same apparatus, instead of continuing to quote the results of his former trials on the small scale, which he admits to be unworthy of full confidence. Had he done so, FRANKLAND feels assured that he would have removed one cause of discrepancy —*videlicet*, his estimate of the value of Boghead cannel when distilled alone, which, as proved, is far too high.

Dr. FRANKLAND acknowledges himself indebted to Mr. A. WRIGHT and Mr. T. G. BARLOW of London, and to Mr. A. KING of Liverpool, for some very important information on this subject—the first gentleman having tested the value of the Boghead cannel during several weeks' working on a very large scale, and the latter two having made a very extensive series of most careful experiments upon a small scale. In Mr. WRIGHT's experiment, three parts of Newcastle coal—Dean's Primrose—and one part of Boghead cannel, were distilled in separate retorts, yielding nine thousand five hundred cubic feet per ton; the mixed gases were burnt in a Number 2 fish-tail burner, 2·5 feet per hour giving light equal to thirteen candles. From this result of the mixed gases, the value of the Boghead was calculated to be 5·44 times that of an equal weight of the Newcastle coal; and therefore, taking the well-known value of Newcastle coal at nine thousand feet per ton—five feet per hour = thirteen candles—it follows that a flame of Boghead gas burning five feet per hour would give a light equal to 57·9 candles, at which rate of consumption the total gas from one ton of Boghead would be equal to 2182·1 pounds of sperm. Mr. KING's result is the average of eleven experiments, each made upon the one-thousandth of a ton; the gas was burnt by a Number 1 fish-tail burner, at rates of consumption varying from 1·38 to 2·04 feet per hour. The value assigned by Mr. BARLOW to Boghead is the average of three experiments, which were also made upon the one-thousandth of a ton of cannel, the gas having been burnt at the rate of from 1·44 to 1·92 feet per hour. If, in the experiments of Mr. KING and Mr. BARLOW, the gases had been burnt at higher rates of consumption, there is no doubt that the equivalent of sperm per ton would have been somewhat higher. In addition to this valuable evidence from gentlemen so intimately acquainted with the subject, there is also the statement of the owners of the cannel, contained in their advertisement, which appears monthly. FRANKLAND considers this statement as good evidence on one side of the question, inasmuch as it is not usual for merchants to underrate the value of the commodities they have to sell. These estimates, along with that contained in Dr. FYFE's printed report to the owners of the coal, are now appended with FRANKLAND's results:—

ESTIMATES OF THE VALUE OF BOGHEAD CANNEL.

Authority.	Cubic feet of gas per ton.	Gas from one ton, = 16 sperm.
Mr. Wright,	11,000	2182·1 pounds.
Mr. Barlow,	13,344	2057·0 "
Mr. King,	13,549	1993·6 "
Dr. Fyfe,	14,800	2283·2 "
Advertisement of proprietors of Boghead cannel,	13,500	1967·1 "
Dr. Frankland's 1st experiment,.	13,240	2387·7 "
Dr. Frankland's 2nd experiment,	14,560	2441·1 "

The above are by no means selected; they include all the experiments upon this cannel, with the exception of the subsequent ones by Dr. FYFE, to which allusion has already been made. It will be seen from this statement, that FRANKLAND's results are considerably higher than those of any other experimenter. This is ascribed to the use of a diaphragm retort, and he believes that it is impossible to obtain numbers so high as his in retorts of the ordinary construction. The relation of these numbers to those employed by Dr. FYFE for comparison with his experiments on the hydrocarbon process—namely, Dr. FYFE's results with seven pound charges, 16,093 cubic feet of gas per ton; gas from one ton = 3253·5 pounds sperm —must convince every candid mind that his results are far too high, and cannot fairly be quoted for comparison with any experiments on the hydrocarbon process.

Having thus obtained a basis of experimental results for comparison with those yielded by the same cannel when treated according to the hydrocarbon process, Frankland proceeds to show the gain in illuminating power which that method exhibits, when the experiments upon it by Dr. Fyfe and himself are compared with these several results; for Dr. Fyfe rightly contends that it is to this test, and not to that of gain in quantity of gas only, that the hydrocarbon process must be submitted.

The comparison which Frankland formerly published, as well as the one previously cited, were founded upon equal consumptions of the respective gases; but Dr. Fyfe prefers to burn each gas to the best advantage, with a given burner—generally a Winfield—at high rates of consumption, and then to calculate the value of each cubic foot. By this method, the comparison may be said to be nearly that of equal light, instead of equal consumpts. Frankland and Fyfe agree on this point, and think that the basis of comparison, especially in gases differing much in richness, ought to be that of equal light and not of equal consumpts. By adopting this plan in the following comparisons, the former has been compelled, in the case of his second experiment, to calculate the hourly consumption of a flame giving a light equal to about fifty candles, as he made no experiment beyond twenty candles. A consumption of ten feet per hour in a Winfield's burner is estimated as being equal to the light of 50·6 candles of one hundred and twenty grains per hour. He does not insist upon the absolute correctness of the gain exhibited by his second experiment, although he believes it to be very near the truth:—

PER CENTAGE GAIN IN ILLUMINATING POWER BY THE HYDROCARBON PROCESS AS APPLIED TO BOGHEAD CANNEL.

Name of Experimenter on Hydrocarbon Process.	Comparison with results obtained with Boghead Cannel alone, by				Proprietor of Boghead Cannel	Dr Frankland's First Experiment.	Dr Frankland's Second Experiment.
	Mr. Wright	Mr. King.	Dr. Fyfe.	Mr Barlow.			
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent
Dr. Fyfe—experiment at Leith gas-works,......	29·7	42·0	24·0	37·6	43·9	15·5	15·9
Dr. Frankland's first experiment,...............	89·6	107·5	81·2	101·1	110·3	73·3	[illegible]
Dr. Frankland's second experiment, ...	105·6	125·0	96·5	118·1	128·1	87·9	[illegible]
Dr. Frankland's third experiment, ...	127·7	149·2	117·6	141·5	152·6	108·1	103·6

These numbers prove, in the most incontestable manner, that there is invariably a very large gain by the employment of the hydrocarbon process, varying with the amount of water-gas used, and with the value at which the gas from Boghead alone is estimated. This gain is even apparent from Dr. Fyfe's own experiments, although its smallness, in comparison with that exhibited by Frankland's own trials, must strike every observer of the above table. The cause of this is, however, made clearly apparent when the mode in which Dr. Fyfe conducted his is taken into account.

Dr. Frankland has found that one water retort is incapable of generating more than one-half the amount of water-gas requisite for one hundredweight of Boghead cannel; and yet, notwithstanding this caution, Dr. Fyfe carbonized two hundredweight of cannel with only one water retort; the water-gas power was, therefore, only one-fourth of what it ought to have been, and, as might naturally be expected, the gain was only one-fourth of that which a properly-conducted experiment would yield. The Editor considers that Dr. Frankland has clearly demonstrated that there is a high gain in the total illuminating power obtainable from a given weight of Boghead cannel by the employment of the hydrocarbon process, and that his former estimate of that gain—at from eighty to ninety per cent. —was by no means too high. Since the publication of his first report on hydrocarbon cannel gas, he has had abundant opportunities of witnessing the working of the process; and although he admits that it is more liable to suffer from the carelessness of workmen than the old process, yet his confidence in its merits, and in its ultimate extensive adoption by gas engineers, continues in every respect unshaken.

Illuminating Power of Gases.—The illuminating power of gas, say Richardson and Ronalds, has generally been estimated by the shadow-test, or by Bunsen's photometer, in conjunction with an experimental meter for accurately measuring the consumption. The standard of comparison used by different experimenters has not always been the same; but a spermaceti candle, consuming one hundred and twenty grains per hour, is now generally adopted.

Illuminating gas must vary in its power of giving light according to the proportion of carbon it contains: but much depends upon the mode of combination in which this element is present, and also upon the manner in which the gas is burned. Thus, carbon, in the form of carbonic acid, is not only useless as a source of light, but actually prejudicial, a very small proportion of carbonic acid in coal-gas reducing the illuminating power to a great extent. Carbon, in the form of carbonic oxide, and as light carbide of hydrogen, is of little or no value as a source of light, these gases burning with a very faint flame. The heavy carbide of hydrogen, as olefiant gas, oil-gas—C_s H_s—and the vapors of naphtha, many and indeed most of which are condensed by chlorine, bromine, and anhydrous sulphuric acid, are the ingredients of coal-gas to which it owes its illuminating power. Hence the value of gas as an illuminating agent has been frequently estimated since the time of Henry, by the amount of condensation which it undergoes when mixed with a sufficient quantity of chlorine to absorb these higher compounds of carbon with hydrogen. Dr. Fyfe relies most implicitly upon the condensation test by chlorine, in connection with what he terms durability, for an accurate indication of the value of any gas; and he has shown, in a great many instances, that these two points give a value which agrees very well with carefully-conducted photometrical experiments. By durability, is to be understood the time during which a certain volume of gas will continue to afford a standard amount of light. Bromine is employed by many to replace the chlorine in condensing the heavy carbo-hydrogens, and is, in many respects, more convenient for manipulation. In both cases, the vapors of these substances left after condensation require to be removed from the gaseous mixture by a solution of potassa before the amount of condensation is estimated. Anhydrous sulphuric acid, obtained by warming the Nordhausen acid, is preferred by others for effecting this condensation, a ball of porous coke attached to a platinum wire being saturated with the acid and thrust up into the mixture of gases. The substances condensed from the gas by all these agents appear to be the same; but from what has been stated with reference to the nature of these condensed hydrocarbons from different specimens of coal-gas, the illuminating power of the gas must depend far more upon the chemical constitution, and upon the amount of carbon which they respectively contain, than upon the volumes which they occupy before condensation; and hence, although the test may be a good one, obtained from the same species of coal under like conditions, and containing the same kinds of hydrocarbons, it is not applicable as a means of setting a value upon gases obtained under different circumstances from different species of coal.

The substances condensed by these re-agents are probably similar, if not identical, in composition with those condensed from oil-gas and resin-gas. It has been ascertained, by comparing the density of ordinary Newcastle coal-gas before and after condensation by bromine, that the vapors of the light-giving portions give a specific gravity ranging from 2·8 to 3·3.

The liquid condensed from resin-gas by Mr. Couerbe yielded six fluids, the nature of which, with the calculated and experimental density of their vapors, are given in the following table:—

No.		Density of Vapor.	
		Calculated.	Found.
1.	$C_4 H_4$,	1·763	2·000
2.	$C_5 H_4$,	2·385	2·254
3.	$C_6 H_4$,	2·806	2·802
4.	$C_7 H_4$,	3·230	3·340
5.	$C_8 H_4$,	3·660	3·765
6.	$C_{28} H_{22}$,	2·665	2·637

The first of these has a specific gravity about equal to the condensable matter in Wigan cannel and Ramsey's cannel, while the third and fourth resemble that from Pelaw, Pelton, and other Newcastle coals. A more elastic vapor probably remained in the gas from which these substances were condensed, which would have a lower specific gravity, and come to resemble the condensable matters and Lesmahagow cannel-gas. The specific gravity of the condensable matter from these gases may be seen from the annexed table by Mr. Evans of the Westminster Gas Works, taken from the *Journal of Gas-lighting:*—

Name of Coal.	Gas per ton.	Condensed per cent by bromine.	Specific gravity of gas.	Specific gravity of condensed matter.	Photogenic Power.	
					Actual.	By analysis.
Boghead,	15,000	30·	·752	1·21	37·75	36·3
Lesmahagow, No. 1,	13,500	16·	·642	1·64	27·1	26·24
Do., No. 2,	13,200	17·	·618	1·43	24·8	24·31
Capeldrae,	14,400	16·5	·577	1·29	19·75	21·28
Arniston,	13,600	17·	·626	1·40	22·50	23·80
Ramsey,	10,300	12·5	·548	1·82	21·40	22·95
Wemyss,	14,300	14·5	·580	1 87	24·50	27·11
Kirkness,	12,800	10·2	·562	1·95	21·20	19·88
Knightswood,	13,200	9·5	·550	2·28	19·00	21·66
Wigan—Ince Hall,	11,400	11·5	·528	1·77	20·00	20·35

The following table shows the illuminating value of the gas obtained from Newcastle coal, and may serve as a fair indication of the character of the gas supplied in the metropolis:—

Name of Coal.	Gas per ton	Illuminating power.	Specific gravity of gas.	Condensation per cent.
Pelton,	11,000	14·0	·430	4·5
Pelton Cannel,	11,500	18·5	·521	10·5
Leverson,	10,800	12·5	·425	4·
Leverson Cannel,	11,600	18·	·523	10·
Washington,	10,000	14·	·430	5·
Washington Cannel,	10,500	18·	·500	10·5
Pelaw,	11,000	12·75	·420	4·5
New Pelton,	10,500	12·	·415	4·75
Dean's Primrose,	10,500	13·5	·430	5·
Ponesfield,	10,500	11·5	·398	3·75
Gosforth,	10,000	12·	·402	4·
West Hartley,	10,500	12·5	·420	4·2
Hastings Hartley,	10,300	12·5	·421	4·3
Blenkinsop,	9,700	14·	·450	6·

The only sure method of arriving at the actual amount of carbon in a gaseous mixture, and at the same time showing the character of the carbonaceous compounds contained in it, is to combine the condensation method with an organic analysis, or by the old plan of combustion with oxygen, as proposed by Henry, noting the quantity of oxygen consumed, and the amount of carbonic acid produced. Thus, a known volume of coal-gas is mixed with an excess of oxygen and exploded, the amount of carbonic acid produced and of oxygen consumed being ascertained. Another equal volume is then treated with an absorbent, as anhydrous sulphuric acid, and after all the residue is again mixed with oxygen, and exploded; the amount of carbonic acid being again ascertained, and deducted from the quantity obtained by exploding the original gas. The quantity of carbon contained in the condensed portion of the gas being thus ascertained, its value as an illuminating agent may be calculated accordingly. There appear to be some compounds of carbon and hydrogen in certain coal gases different from light carbide of hydrogen, and which are not condensed by any of the absorbents named, and which, nevertheless, add much to the illuminating power; so that calculations based upon the above method of analysis will prove rather below than above the true value of the gas.

In estimating the value of gases by the photometer, it is absolutely necessary to burn the gas in a great variety of ways—with differently constructed burners, in different quantities, and under varying amounts of pressure—in order to ascertain under what conditions it affords its full value as an illuminating agent. A gas which is very rich in heavy hydrocarbons cannot be burned to advantage with a burner adapted for less rich gas—the apertures require to be smaller, in order to bring more oxygen into contact with each flame; and a poor gas, on the contrary, burned in a manner suitable for rich gas, will not afford its maximum effect, in consequence of too much air being brought into contact with the flame.

If the central ring of an argand burner, consuming oil without smoke at its maximum degree of brightness, be closed so as to exclude the inner current of air from the flame, the brightness is visibly diminished, but, strange as it may appear, the amount of light, as indicated by the photometer, is increased. A greater number of the particles of carbon are rendered luminous before being consumed, by diminishing the supply of air in this manner, and a greater quantity of light diffused, although the light is not so brilliant. By increasing the supply of air, much of the carbon is consumed at once, without taking a solid form in the flame; more heat is then produced, and those particles which are solid in the flame are more intensely heated: quantity of light is then sacrificed to intensity. Gas has little tendency to smoke. It is generally better suited to the production of intensity than quantity of light; and for this reason, in comparing the illuminating power of different gases with each other, it would be better to adopt as a standard the flame of some gaseous mixture of known composition, instead of the spermaceti candle, which is calculated for affording quantity rather than intensity of light.

The more carbon there is contained in gas the heavier it is, and specific gravity has, therefore, been often resorted to, as an indication of the relative value of different gases. If carbonic acid has been completely separated, and no excess of carbonic oxide is present, the specific gravity may furnish an important indication to the manufacturer of the value of gas made under similar circumstances; but it can never replace an analysis in judging of the value of different gases, as the amount of carbonic oxide will vary with the kind of coal used, and the method of conducting the distillation, the specific gravity of which is very nearly equal to that of olefiant gas.

Mr. WRIGHT employs a small balloon, capable, when filled, of holding one thousand cubic inches of gas, which is gauged by a ring fitting its largest diameter when full. The weight of the balloon and car being known, and the air expelled, it is filled with gas; weights are then placed in the car until it remains in equilibrium in the air. The data thus obtained, with corrections for temperature and pressure, afford an approximate means of ascertaining the specific gravity of the gas. Mr. WRIGHT has constructed a table, by simple reference to which, and a knowledge of the weights required to balance the balloon, the specific gravity may be read off for any variations of temperature and pressure. Little reliance is, however, placed by gas engineers upon any test of illuminating power based upon specific gravity, as this is often considerably increased by the presence of carbonic acid and carbonic oxide, which add to the weight without increasing the illuminating power of gas.

CHRISTISON and TURNER observed the following relations between the specific gravity and illuminating power of coal and oil gas:—

Specific gravity.		Relation of Illuminating power	
Of Coal-gas.	Of Oil-gas	Of Coal-gas.	Of Oil-gas
0·659	0·118	100	140
0·578	0·910	100	225
0·605	1·110	100	250
0·407	0·940	100	354
0·429	0·965	100	356
0·508	1·175	100	310
0·529	0·986	100	272 average.

According to a report made by HEDLEY to Parliament, the illuminating power of coal-gas, in twelve principal districts of England, amounts to between 4·408 and 1·645 times that of a tallow candle—six to the pound; but ordinarily about two or three times, when the consumption varies from 2·3 to 1·5 cubic feet per hour, and the specific gravity from 0·58 to 0·412.

With the same burner and gas, the amount of light depends upon the height of the flame, which practically, the pressure being nearly constant, is regulated by the position of the cock, or by varying the size of aperture in the burner. According to CHRISTISON and TURNER, the advantage increases with the height of the flame, but to a limited extent only, and for a simple jet in the following proportion:—

Length of the flame in inches.	Intensity of the light from equal quantities of		Coal-gas.		Oil-gas	
	Coal-gas	Oil-gas.	Intensity of the light.	Gas consumed.	Intensity of the light.	Gas consumed.
1	—	100	—	—	22·0	33·1
2	100	122	55·6	60·5	63·7	78·5
3	109	159	100·0	101·4	96·5	90·0
4	131	181	150·0	126·3	141·0	118·0
5	150	174	197·8	143·7	178·0	153·0
6	150	—	247·4	182·2	—	—

Thus the point at which further advantage ceases to result on raising the flame of oil-gas is four inches, whilst for coal-gas it is five inches, which in general requires the flames to be higher. The consumption of gas and the intensity of the light increase together, but the latter in a more rapid ratio up to a certain point. This occurs to a still greater extent with argand burners, for which, with the same consumption of gas, these observers found the intensity of the light to be,—

	100	282	560	582	582	504	
At a height of	0·50	1	2	3	4	5	inches.

According to FYFE's experiments upon different burners, in which he probably used a better kind of coal-gas, the increase is as follows:—

With twenty-four apertures of one-fortieth of an inch, the diameter of the perforated ring being seven-eighths of an inch,........	100	121·8	—	188·5	—	236·6	—	235·4
With forty-two apertures of one fiftieth of an inch, the ring being twenty-one twentieths of an inch in diameter,.	100	136·6	—	176·2	—	194·8	—	242·3
Height in inches,...	1	1·5	1·75	2	2·5	2·75	3	3·5

Lastly, his experiments gave a view of the intensity of the light produced by the same quantity of gas in different burners, when separately compared at the most advantageous height of the flame:—

		Bat's-wing.			Argand burners.	
Burners.	Simple jet.	Small.	Large.	Fish-tail burner.	With 24 holes.	With 42 holes.
Quantity of light from the same amount of gas,	100 ..	135 ..	164 ..	138 ..	183·5 ..	182·3

According to the observations of HEDLEY, already quoted, which were made in the gas-works at Sheffield, the intensity of the light of a simple four-inch jet is to that of a 3·5 inch argand flame—from fourteen apertures—as 1 : 4·4 to 4·8, the amounts consumed being as 1 : 3 cubic feet, which corresponds to a greater amount of light from the argand burner by from 1·47 to 1·6 for the same quantity of gas. From the general report of the same engineer upon the principal gas-works in England, it is found—in the case of coal-gas—the average specific gravity being 0·476, that a simple jet, four inches in height, consumes on the average one cubic foot per hour.

The superiority of the flat flames over the simple round ones, explains an observation which has been made with regard to the argand burners. When the apertures in it are placed so far apart as to form a circle of distinct jets, the effect is one-third weaker, with the same current of gas, than when the jets—of one-sixth, to one-eighth of an inch—unite into a single flat ring.

The subjoined experiments on the illuminating power of Wigan cannel-gas with different burners have been recorded by Mr. ALFRED KING:—

	One-half foot.	One foot.	One and a half feet.	Two feet.	Two and a half feet.	Three feet.	Three and a half feet.	Four feet.	Four and a half feet.	Five feet.	Five and a half feet.
Single Jet:											
Consumption per hour.........	·5	1·	—	—	—	—	—	—	—	—	—
One foot = candles...........	2·15	2·6	—	—	—	—	—	—	—	—	—
One foot = grains of sperm.,..	258·3	311·8	—	—	—	—	—	—	—	—	—
Lancashire Fish-tail, No. 0:											
Consumption per hour,........	·5	1·	1·5	—	—	—	—	—	—	—	—
One foot = candles,..........	1·78	2·18	1·76	—	—	—	—	—	—	—	—
One foot = grains of sperm.,..	214·1	262·5	211·9	—	—	—	—	—	—	—	—
Lancashire Fish tail, No. 1:											
Consumption per hour,........	·5	1·	1·5	2·	—	—	—	—	—	—	—
One foot = candles,..........	1·76	2·65	2·55	2·53	—	—	—	—	—	—	—
One foot = grains of sperm.,..	211·3	317·9	306·5	303·7	—	—	—	—	—	—	—
Lancashire Fish-tail, No. 2:											
Consumption per hour,........	·5	1·	1·5	2·	2·5	3·	—	—	—	—	—
One foot = candles,..........	2·26	3·11	3·5	3·76	3·79	3·66	—	—	—	—	—
One foot = grains of sperm.,..	271·2	373·3	420·6	455·7	455·7	439·4	—	—	—	—	—
Lancashire Fish-tail, No. 3:											
Consumption per hour,........	·5	1·	1·5	2·	2·5	3·	3·5	—	—	—	—
One foot = candles,..........	2·26	3·48	3·86	4·07	4·07	4·18	4·1	—	—	—	—
One foot = grains of sperm.,..	271·2	417·4	463·6	488·3	488·3	501·9	492·8	—	—	—	—
Lancashire Fish-tail, No. 4:											
Consumption per hour, ...	·5	1·	1·5	2·	2·5	3·	3·5	4·	—	—	—
One foot = candles, ...	2·38	3·49	4·00	4·17	4·74	4·5	4·41	4·3	—	—	—
One foot = grains of sperm.,..	285·5	419·5	484·4	500·5	566·7	539·9	530·1	516·6	—	—	—
Bat's Wing:											
Consumption per hour,........	·5	1·	1·5	2·	2·5	3·	3·5	4·	4·5	5·	—
One foot = candles,..........	1·83	3·01	3·73	4·1	4·12	4·31	4·3	4·46	4·32	4·4	—
One foot = grains of sperm.,..	220·	361·6	448·3	492·3	494·8	578·1	516·2	535·1	519·	528·9	—
Sixteen-hole Argand, small holes in ring 0·82 in diameter:											
Consumption per hour,........	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,..........	—	0·323	1·02	1·9	2·6	3·27	3·72	3·84	3·96	-	—
One foot = grains of sperm.,..	—	38·76	123·3	228·7	313·	393·3	446·4	461·7	479·2	-	—
Winfield's twenty-eight hole Argand, registered July 25, 1848, with slightly conical chimney:											
Consumption per hour,........	—	1·	1·5	2·	2·5	3·	3·5	4·	4·5	—	—
One foot = candles,..........	—	0·341	1·16	2·26	2·71	3·5	3·72	3·84	4·	-	—
One foot = grains of sperm.,..	—	41·2	139·1	271·3	325·6	420·5	446·4	461·7	481·	—	—
Winfield's fifty-eight hole Lucent Argand, registered March 20, 1845:											
Consumption per hour,........	—	—	1·5	2·	2·5	3·	3·5	4·	4·5	5·	5·5
One foot = candles,..........	—	—	0·318	0·75	1·09	1·57	2·09	2·59	3·07	3·82	4·5
One foot = grains of sperm.,..	—	—	38·2	87·5	131·8	188·4	251·1	311·3	368·9	458·8	540·

The following experiments upon the illuminating power of Newcastle cannel-gas, were made by Mr. WRIGHT with the burners used in London for consuming that kind of gas:—

The No. 1 Scotch fish-tail gives a flame fully spread with ·85 inch pressure, and when burning at the rate of 1·4 feet per hour, beyond which point it begins to show streaks of blue.

The No. 2 Scotch fish-tail is fully spread with ·9 inch pressure, and when burning at the rate of 2·4 feet per hour.

GUISE's burner is an argand with twenty-six holes, the inner diameter of the ring being six-tenths of an inch, and the outer nine-tenths of an inch. It has a metal button, five-tenths of an inch diameter, one inch above the face of the burner. The glass chimney is a straight cylinder, two inches diameter and six inches long.

With a three-tenth inch pressure, and a consumption of 4·5 feet per hour, the flame becomes irregular, and has a tendency to deliver smoke.

The standard candle used by Mr. WRIGHT consumed one hundred and thirty grains per hour, and for this, to insure a greater regularity of flame, a No. 2 fish-tail, burning ·4 feet per hour, was substituted, and found exactly equal to the candle.

In the first of the following tables, the results are multiplied by one hundred and thirty, and divided by one hundred and twenty, so as to reduce them to a standard candle of one hundred and twenty grains per hour, as done by Mr. KING:—

Consumption per hour.	One foot.	One and a half feet.	Two feet.	Two and a half feet.	Three feet	Three and a half feet.	Four feet	Four and a ha feet.
Scotch Fish-tail, No. 1:								
One foot = candles,	4·875	5·02	—	—	—	—	—	—
One foot = grains of sperm.,	585·	602·	—	—	—	—	—	—
Scotch Fish-tail, No. 2:								
One foot = candles,	5·05	5·77	5·95	5·84	5·53	—	—	—
One foot = grains of sperm.,	606·	690·	714·	700·	563·	—	—	—
Guise's Argand:								
One foot = candles,	—	1·08	1·85	3·12	4·85	4·95	5·77	6·74
One foot = grains of sperm.,	—	129·	222·	374·	582·	594·	692·	80[illegible]·

Mr. WRIGHT, however, prefers the subjoined form of quoting the above results:—

SPERMACETI CANDLES OF ONE HUNDRED AND THIRTY GRAINS PER HOUR.

No. 1, *Scotch Fish-tail:*													
Gives light = ...	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	6	8	....	....	....	....	candles.
When burning.....	·15	·2	·3	·4	·6	.9	1·3	1·8	....	....	....	....	feet per hour.
Feet of gas required to produce a light = one candle, ...	1·2	·8	·6	·4	·3	·225	·217	·225					
No. 2, *Scotch Fish-tail:*													
Gives light = ...	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	6	8	10	12	14	16	candles.
When burning.....	·15	·2	·3	·4	·6	·9	1·2	1·5	1·8	2·2	2·6	3·2	feet per hour.
Feet of gas required to produce a light = one candle, ...	1·2	·8	·6	·4	·3	·225	·2	·1875	·18	·183	·185	·2	
Guise's Argand:													
Gives light = ...	2	4	8	12	16	20	24	28	....	....	....	....	candles.
When burning.....	1·7	2·1	2·6	3·1	3·5	3·19	4·2	4·5	....	....	....	....	feet per hour.
Feet of gas required to produce a light = one candle, ...	·85	·525	·325	.258	·219	·195	·175	·160					

Mr. BARLOW has recorded some experiments made by him with different burners on gas manufactured from a mixture of Pelton, Felling, and Dean's Primrose, all first-class Newcastle gas coals, the average produce being eight thousand five hundred feet per ton of coal. The burners he used were:—

1st. A Number 3 fish-tail, or union jet.

2nd. A Number 5 bat's-wing.

3rd. A common argand, with fifteen large holes in a ring ·85 inch diameter, and a cylindrical chimney-glass 7 inches high.

4th. A Platow's registered argand, with large holes in a ring ·9 inch diameter, with inside and outside cone, and cylindrical chimney-glass 8·5 inches high.

5th. A Bizuner's patent Number 3 argand, with twenty-eight medium-sized holes in a ring ·75 inch diameter, and cylindrical chimney-glass 8·65 inches high.

6th. A Winfield's registered argand, with fifty-eight medium-sized holes in two rings of twenty-nine holes in each, the mean diameter being one inch, with deflecting button inside and gauze below; bellied chimney-glass eight inches high.

7th. A Leslie's patent argand, with twenty-eight jets in a ring ·95 inch diameter, and chimney-glass 3·5 inches high.

8th. A Guise's registered shadowless argand, with twenty-six large holes in a ring ·85 inch diameter, and deflecting button; cylindrical chimney-glass 6·1 inch high, and glass reflecting cone to outside gallery.

On an average of numerous trials the annexed results were obtained :—

SERIES NO. I.

Burner.	Consumption per hour.	Value of one cubic foot in grains of sperm.	Standard candles per cubic foot.	Value of eight thousand five hundred feet of gas in pounds of sperm.
No. 2,	4·9	289·	2·4	351·
No. 3,	5·5	343·	2·85	416·
No. 5,	5·5	374·	3·11	447·
No. 6,	5·5	337·	2·8	409·
No. 8,	5·5	350·	2·91	425·

SERIES NO. II.

No. 1,	5·5	276·	2·3	335·
No. 2,	5·0	290·	2·41	352·
No. 3.	5·5	341·	2·84	414·
No. 4.	5·5	348·	2·9	422·
No. 5.	5·5	380·	3·16	461·
No. 6.	5·5	335·	2·79	406·
No. 7.	4·1	369·	3·07	448·
No. 8,	5·5	364·	3·03	442·

It is quite evident from these experiments that the No. 6, or Dr. Fyfe's Aberdeen argand, required a longer consumpt than 5·5 feet per hour to bring out the full effect of Newcastle coal-gas of the quality used in this case, for, when the consumpt was increased to 6·5 feet per hour, it gave results equal to any of its compeers at 5·5 feet. No. 2 and No. 7 burners were tried with the utmost quantity which could be consumed in them without smoking or burning advantageously.

Though these experiments indicate the relative adaptation of the several burners for the combustion of Newcastle coal-gas, they must not be taken as settling the question of the practical value of each. Some of them cast shadows, which detract considerably from the light they yield when placed above the level of the eye; this is particularly the case with No. 5, which otherwise gives the best results. Others, like No. 7, require a perfect uniformity of pressure, and an absence of all currents of air. Taking all things into consideration, No. 8 is, perhaps, the one to which these objections least apply, and it gives the next largest amount of light for the gas consumed, though the slight advance upon the old argand, as constructed twenty-five years since, cannot fail to be remarked.

Glass chimneys are not so requisite for gas as for lamp flames, and their effect is quite different from that exerted upon the wick flame of a lamp. The jet of gas, as it leaves the burner, is in far more correct relation to the air, than is the case with the gas produced at the burning margin of the wick.

Argand wick flames require a strong draught, and never burn without smoke, unless a chimney is used; with gas flames, the glasses are used rather to steady the flame than to insure its perfect combustion: they are always made shorter than the glasses of oil-lamps. If too high chimneys are used, the draught of air soon cools the base of the flame, and the air becoming mixed with the gas, a diminution of the light results, which is caused by the combustion of too much carbon simultaneously with the hydrogen; hence but little is momentarily separated in the flame. A striking proof of this is afforded by the well-known experiment, in which a closed cylinder of wire-gauze, through which flame cannot be communicated to a combustible mixture, is adapted to a gas-burner. The jet of gas which, without the case of wire-gauze, yields a perfect flame, becomes intimately mixed with air in the interior of the case, and on its exit burns with a pale blue light, because the separation of carbon in the flame no longer occurs, both carbon and hydrogen being burnt simultaneously. This experiment gives an important hint on the general management of the draught in illumination. The same result may be observed when the gas is allowed to escape with too great velocity; and, if the proper limit is exceeded, the flame may be extinguished by being too much cooled: with a certain velocity, the current will not ignite for a distance of several lines from the aperture, and then burns with a faint blue flame, the gas having become mixed with air.

It is by taking advantage of this effect of a strong current of air, that the highly carbonaceous vapors of oil of turpentine, coal-tar naphtha, and similar substances, may be burned without smoke, as in BUSSON and ROUEN'S apparatus, or in HOLLIDAY'S lamps. The oils being allowed to escape in the form of a jet of vapor, under a pressure varying, according to circumstances, from four to twenty-four lines of mercury, the excess of carbon is brought to a proper proportion by the admixture of air, without interference with the order of combustion. In this manner brilliant flames, free from soot, are produced.

Among the arrangements which increase the light by raising the temperature of the air, the burner invented by M. PARISOT of Paris is distinguished by its simplicity and great facility of construction. It admits the air by narrow passages between two thick concentric cylinders or cones, about four inches in height. The gas escapes by a circular slit, easy to clean. This burner gives a full light and a very steady flame.

Application of Gas as a source of Heat.—Gas has long been employed as a source of heat in chemical and pharmaceutical laboratories, but it is only during the last few years that it has been more extensively used for cooking, warming apartments, *et cetera.*

Comparison of the various methods of Illumination with each other.—In the foregoing remarks, the relative illuminating values of the various methods of producing artificial light have generally been shown, without reference to the cost of the light. This still remains to be considered, in order to estimate their relative economy. PECLET, in the following sketch, has in each case taken the cost into account; but this will vary with the rise and fall of markets, and with the locality. The price of a pint of oil—0·9 lb.—is here fixed at about fivepence; of one pound of tallow candles at sevenpence, wax candles at two shillings and twopence, stearin candles at one shilling and fourpence; a pint of illuminating spirit—0·8 lb.—at eightpence; of one hundred cubic feet of coal-gas at sevenpence; and lastly, of one hundred cubic feet of oil-gas at two shillings and threepence.

Means of Illumination.	Intensity of the light.	Consumption of illuminating material per hour.	Illuminating power, Carcel's lamp = 100.	Price of 100 grammes of illuminating matter	Cost of the light per hour in pence	Cost of a light of the same intensity per hour in pence
Tallow candles, six to lb.,	10·66	8·5	51·04	1·5	0·125	1·163
Wax " six "	14·60	9·6	61·57	5·	0·461	3·155
Stearin " five "	14·40	9·3	66·58	3·2	0·298	2·066
Kitchen lamp,	6·65	8·0	33·60	1·4	0·083	1·246
Lamp with flat wick,	12·50	11·0	47·50		0·114	0·912
Astral lamp,	31·00	26·7	48·70		0·280	0·8[illegible]3
Sinumbra lamp,	56·00	37·1	63·0		0·385	0·687
Lamp with inverted reservoir,	90·00	43·0	87·8		0·446	0·495
Hydrostatic lamp,	45·00	17·26	109·2		0·179	0·398
Carcel's lamp,	100·00	42·0	100·0		0·435	0·435
Vapor lamp,	130·70	151·0	36·2	1·3	2·013	1·207
		C. F.		Per 100 C. F.		
Coal-gas,	127·00	8·70		7·0	0·580	0·456
Oil-gas,	127·00	2·43		19·2	0·630	0·357

The light of wax candles is the most expensive, then that of stearin candles and the vapor lamp, which are also costly. There are, however, few instances in which public opinion and scientific estimation of the value of an article are so much at variance as with reference to the means of illumination in general; occasional deceptions, such as occur in the lamp of BENKLER, not being taken into consideration. A glance at the last column in the above table shows that the modes of illumination which, on account of their supposed cheapness, are partly used by the wealthy and exclusively by the poor, are those which—excluding articles of luxury, such as wax, *et cetera*—cost most in producing a certain degree of brilliancy. A given amount of light yielded by tallow candles costs from three-fifths to twice as much as when it is obtained from the lamp of CARCEL; with the kitchen lamp it costs nearly three times, and by the lamp with the flat wick more than twice as much.

The more ordinary light-giving materials have recently been examined, and compared with the light obtained from what is called common or thirteen-candle coal-gas. Tried by the photometer:—

One thousand cubic feet of gas were found equal to the light of 312,000 grains, or $44\frac{4}{7}$ pounds of sperm candles.
" " " " 341,750 " $48\frac{6}{7}$ pounds of carefully-snuffed wax candles.
" " " " 358,000 " $51\frac{1}{7}$ pounds of stearic acid candles.
" " " " 370,540 " $52\frac{9}{10}$ pounds of best mould candles.
" " " " 381,000 " $54\frac{3}{7}$ pounds of best dip candles.
" " " " 417,220 " $6\frac{1}{2}$ gallons of purified colza oil, specific gravity 915.
" " " " 366,310 " $5\frac{9}{10}$ gallons of sperm oil, specific gravity [illegible].

As the price of gas varies in different parts of the United Kingdom from four shillings and sixpence to ten shillings per thousand cubic feet, to obtain the relative cost it is necessary to multiply the prices of the other materials per pound with the numbers in the above table.

Thus, with gas at four shillings and sixpence per thousand cubic feet, and dip candles at sevenpence per pound, the cost of an equal amount of light from the two sources will be as four shillings and sixpence to one pound ten shillings and tenpence.

The great obstacles to the more general introduction of gas-light into private houses, are the difficulty of placing the light in such a position as to be available for all purposes, and that of reducing the consumption to the requirements of the consumer. A candle or a lamp can be placed wherever it is wanted, while a gas-light, even when flexible india-rubber tubes are used, is always more or less a fixture. The burners in common use are also calculated for giving more light than is required for one or two persons; and hence, though the light from gas is so very much cheaper, yet a larger quantity of light than is absolutely necessary being generally employed wherever gas is introduced, the actual saving by its introduction is not so great as the difference of price in the light would make it appear.

The foregoing tables also show that the most economical light is obtained from the best constructed lamps, which, in addition to being costly themselves, also consume large quantities of oil, and are therefore not economical when used by a single person. There still appears much room for improvement in the adaptation of good lamps to the requirements of small consumers. A lamp which would give the light of one or two spermaceti candles, and yet be relatively as economical in the consumption of oil as CARCEL'S or the French moderator lamp, would probably command an extensive sale.—*Richardson and Ronalds.*

Detection of Sulphide of Hydrogen, Bisulphide of Carbon, and Atmospheric Air in Coal-Gas.—A quick approximative method of estimating the above in coal-gas, which has long been considered a great desideratum by chemists, has been given by THORNTON J. HERAPATH. The reagents and apparatus required are:—

1. A weak aqueous solution of caustic potassa.
2. A strong alcoholic solution of caustic potassa.

3. A solution of the nitrate or acetate of lead.

4. A standard solution of lead, containing one, two, or three one-hundredths of a grain of metallic lead, as nitrate or acetate, to one hundred or one thousand water-grain measures of solution.

5. A standard meter, such as is generally used for testing the illuminating quality of coal-gas.

6. Two Liebig's triangles, and

7. Three graduated tubes or colorimeters of uniform bore. The aqueous solution of potassa is used to absorb the sulphide of hydrogen, whilst the alcoholic is afterwards employed to dissolve the bisulphide of carbon vapor, which it converts into xanthate of potassa, a salt decomposable by heat into sulphide of potassium, sulphide of hydrogen, *et cetera*, as exhibited by the equation :—

$$\underbrace{C_4\,H_5\,KO\,C_2\,S_4}_{\text{Xanthate of potassa.}} + \underbrace{2\,HO}_{\text{Water.}} = \underbrace{C\,O_2}_{\text{Carbonic acid.}} + \underbrace{HS}_{\text{Sulphide of hydrogen.}} +$$
$$\underbrace{C\,S_2}_{\text{Bisulphide of carbon.}} + \underbrace{K\,S}_{\text{Sulphide of potassium.}} + \underbrace{C_4\,H_5\,O,\,HO.}_{\text{Alcohol.}}$$

In testing a gas by this method, one proceeds as follows:—The two triangles having been properly filled, the one with the aqueous, and the other with the alcoholic solution of caustic potassa, they are connected together by a piece of sheet caoutchouc in the usual way, and attached to the exit pipe of the standard meter, care being taken to place the one containing the aqueous solution next to the exit pipe. A known quantity, say ten, twenty, or thirty cubic feet of the gas to be examined, is then tardily transmitted through the triangles; the apparatus is slowly disconnected, and the contents of the triangles are separately poured into two different colorimeters. The solutions are next diluted with a little distilled water, mixed with a few drops of a solution of lead, and the alcoholic solution is heated to the boiling point, or until no further darkening in color ensues. The caustic alkali of both solutions is then supersaturated either with acetic or with very dilute nitric acid, and water is added to dilute to the required degree. As the sulphide of lead produced by the decomposition of the xanthate of potassa that was contained in the alcoholic solution is generally, if not always, much less in quantity than that produced by the sulphide of hydrogen absorbed by the aqueous solution of the alkali, it is advisable to dilute the former with less water. The depth of tint communicated to the fluid by the sulphide of lead in the alcoholic solution, is then compared with that produced, by adding the standard solution of lead, drop by drop, from a graduated tube, into a third colorimeter, which is filled nearly up to the same mark with distilled water, mixed with a few drops of pure citric acid, and of a solution of sulphide of hydrogen. So soon as the tints correspond, the measure of the solution in the two colorimeters is accurately adjusted by adding a little more water either to the one or the other; a little more of the standard solution of lead is then poured in, if requisite, to the trial colorimeter, and the number of measures of the standard solution that has been taken is carefully noted. The operation is then repeated with the contents of the other colorimeter, containing sulphide of lead from the aqueous solution of potassa; and the number of measures of the standard solution of lead taken, is again read off. By a simple calculation are estimated the relative proportions of bisulphide of carbon and sulphide of hydrogen, by weight, contained in the gas examined.

For example, let a represent the quantity by weight of bisulphide of carbon which is equivalent to the lead contained in one thousand grain measures of the standard plumbous liquid; b the quantity of sulphide of hydrogen equivalent to the lead contained in the same bulk of the standard solution taken, as before explained, to produce a tint equal in intensity to that of the sulphide of lead in the alcoholic solution; and d the number of measures of the same solution by the aqueous solution:—then the proportion by weight of sulphide of carbon and sulphide of hydrogen contained in the number of cubic feet of gas operated upon, is obtained in the following equations :—

$$\text{Bisulphide of carbon,}\ldots\ldots\ldots = \frac{c+a}{1000} + 2\text{—nearly.}$$
$$\text{Sulphide of hydrogen,}\ldots\ldots = \frac{d+a}{1000}$$

And as one hundred cubic inches of bisulphide of carbon vapor, and sulphide of hydrogen, weigh respectively at 600°, and 30 inches of Bar. 81·8167 and 36·331 grains, the result of the above calculation affords the means of ascertaining the proportion of these two substances by volume.

The presence of atmospheric air in coal-gas can be readily detected, by collecting a portion of the gas over mercury, and then passing up, first a few drops of caustic potassa, and afterwards a drop or two of a solution of pyrogallic acid. If the liquid assume a blood-red hue, oxygen, indicating the presence of atmospheric air, is mixed with the gas.

It would be quite out of place in a work like this to enlarge upon the different varieties of gas-burners, as that subject relates more particularly to mechanics. Still the Editor will cursorily glance at them, and for this purpose he cannot do better than append the following remarks from the able work of Drs. Richardson and Ronalds :—

The Burners.—From the leaden pipes—in the circuit of which the meter is placed, if used at all—the gas passes to the *burners*, each of which is furnished with a separate brass tap. Good tight stopcocks are much more difficult to make for so light a substance as gas, than for liquids. The burners are very similar to those used for lamps, but as neither wick nor oil level requires special consideration, the management of the gas-burners is comparatively simple. The amount of gas consumed in a given time, however, must bear a proper relation to the supply of air, that the flame may not smoke or burn with a blue flame. This is regulated partly by the tap attached to the burner, and an excess of gas is avoided by making the aperture of the burners very small, which increases the velocity of the current. The same quantity of gas issuing from a wide orifice would produce a thick, short, and dull flame, because the surface in contact with the air would be increased. No gas flame should be allowed to issue from a wide opening, for the same reason that thick massive lamp-wicks are not desirable.

When the burner has a single aperture of the diameter of a bristle, a *simple jet* is produced in the form of a long, thin, conical flame. The *bat's-wing*, or flattened flame, which the gas forms when it issues from a narrow slit, instead of a round aperture, is much more appropriate. A similar and equally good flame is produced by a burner with two apertures close to each other, the channels of which are inclined inwards, so that both the currents of gas cross each other at the base. They then form a flat flame spreading out in the form of an inverted triangle, and the burner is called a *fish* or *swallow-tail*.

Simple flames of this kind are generally burnt without any chimney. When a greater quantity of light is required, a greater intensity of flame, the argand burner, Fig. 122, is generally chosen. The gas from the pipe enters the annular space, *a a*, which is closed above by the flat plate, *b*, Fig. 123. In this plate are a number of fine apertures, arranged in a circle, and so near to each other that the separate flames unite to form a hollow cone. The gallery, *c*, supports the chimney, *d*; and to produce an internal current of air, *e*, is open at the sides. The distance between the apertures in these burners varies with the quality of the gas, as does the size of the aperture itself. An aperture $\frac{1}{32}$ of an inch is often used for coal-gas, and one of $\frac{1}{50}$ of an inch for oil-gas; for the former they should be $\frac{1}{8}$th of an inch, for the latter $\frac{1}{6}$th of an inch apart. These dimensions are, therefore, larger for coal-gas than for oil-gas, the latter possessing double the illuminating power of the former. The holes should be as uniformly and accurately bored as possible; if this is not done, there will be parts of the flame which will smoke. Sometimes the heat of the flame is applied to warm the current of gas before it issues from the burner, by which means the flame is less cooled, and whiter light is produced. For this purpose, the gas-pipe is formed into several revolutions at a certain height above the flame.

Fig. 122.

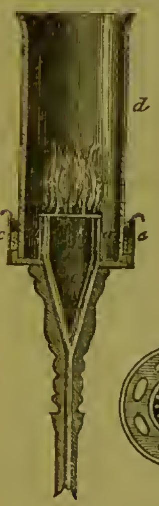
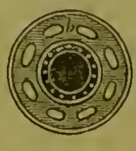


Fig. 123.



An important improvement upon ARGAND's burner for illuminating public places, bridges, *et cetera*, where one large lamp, and a very intense light, is preferred to a number of small ones, is the *bude burner*, proposed by GURNEY, upon the principle of FRESNEL's lamp. Two, three, or more hollow ring tubes, each furnished at the top with a circle of holes, form the principal part of the burner, and are connected at bottom with parts of the gas-pipe bent horizontally, from which they receive the gas. Each inner ring is placed somewhat higher than the one before it, so that a number of concentric flames are produced, the light of which is thrown by reflectors in the proper direction. The bude burner must not be confounded with the *bude light* of the same inventor, which is produced by conveying oxygen into the inner space of an argand oil-lamp. A similar effect to that of the bude burner, is produced by a number of single flat flames arranged in a ring. The Victoria Bridge at Manchester, for instance, is lighted by such a burner, consisting of two concentric rings, each containing twelve, therefore altogether containing twenty-four flat flames; the inner ring, four inches in diameter, stands one inch higher than the outer, which is six and a half inches in diameter, the whole thus being rounded off in the shape of a rose. A great variety of gas-burners have been successively brought into public notice, all of which lay claim to the production of an increase of light, with a smaller consumption of gas. It is impossible, however, from a mere inspection of the flame produced by these burners, without accurately measuring the amount of gas consumed by each, to arrive at any conclusion as to which form is the most economical or generally desirable. Until, as RICHARDSON and RONALDS justly remark, impartial comparative experiments have been instituted with them all, decided preference cannot be awarded to any one in particular.

Fig. 124 is a representation of WINFIELD's lucent burner, in which the Liverpool button is applied to an argand gas-burner, and the peculiar form of chimney causes an external current of air to impinge at a certain angle upon the flame, producing the same effect as the metallic cone in the solar lamp; a basket of wire-gauze is fitted into the crutch of the burner, which moderates the supply of air from below, and prevents the flickering caused by sudden draughts. By fixing the chimney to a circular collar, which screws up or down upon the triangular support, Mr. LOWE is enabled, in his improvement upon this form of burner, to alter the direction of the external current caused by the contraction of the chimney; and by converting the button into a screw, its height can also be altered, and the internal current regulated.

Fig. 124.

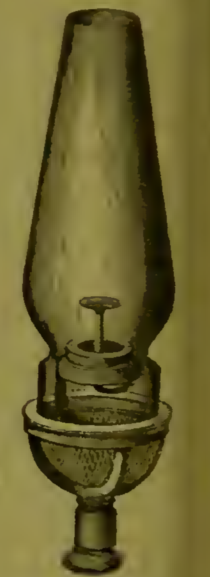
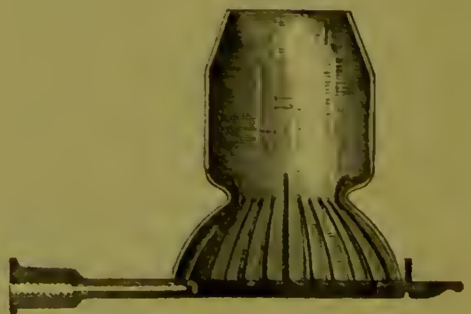


Fig. 125 shows a form of burner, patented by Mr. LESLIE, in which the gas is caused to flow through a number of small copper tubes, instead of from the apertures of an argand burner. The object of this is to effect a more complete combustion of the gas, by surrounding each single jet with abundance of air as it issues from the orifice. A low form of chimney or combustion-chamber is adapted to this burner, which

Fig. 125.



diminishes the velocity of the draught. If the gas be impure, the orifices of the copper tubes become stopped up either with sulphide of copper or ammoniacal compounds, and require to be cleansed with a stiff brush. The only effectual remedy for this objection to the burner, is the use of purer gas; and this must be obtained, when not supplied in a pure state from the gas-works, by the use of a separate purifier in each house. —*Richardson and Ronalds.*

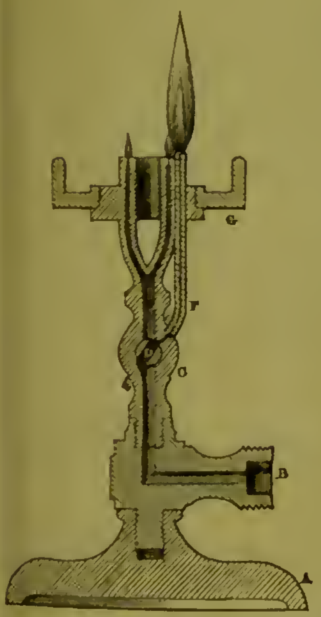
Ventilation of Gas-burners.—Serious objections stood in the way of using gas-light in private dwellings at first, in consequence of the impurities contained in the gas, the great heat produced, and the large quantity of carbonic acid evolved; and to avoid inconvenience, some system of ventilation had to be adopted; but now, owing to the general purity of the gas, and the loftiness of rooms, this is not necessary.

HOFMANN'S BURNER.—It will not be out of place here to remark, that the very extensive and daily increasing application of gas as a source of heat, suggested to HOFMANN a small contrivance which is intended to facilitate the operations of the analyst.

The ordinary argand gas-burner, which is almost universally employed for heating small vessels, such as flasks, retorts, and test-tubes, is not adapted to the purposes of the blowpipe. In operations with the latter instrument, a simple jet of gas is required, issuing from a cylindrical orifice of rather considerable dimensions, the necessary amount of gas being adjusted by the stopcock. This simplest of all gas flames serves equally well for oxidation and reduction, and exhibits the phenomena of color in the most conspicuous manner.

The ordinary method of analysis being a combination of testing in the moist way and by the blowpipe, it is necessary either to use the two gas lamps—the one with the argand burner, the other with the single jet—or to have a gas-stand so arranged as to admit of screwing on either the one or the other. But as it is inconvenient to multiply the number of gas lamps, especially in a laboratory in which several analytical students are working, and as unscrewing hot gas-jets is a most unpleasant operation, the above chemist endeavored to unite the two jets in one stand, dispensing, at the same time, with the necessity of taking the apparatus to pieces.

Fig. 126.



The object in view is accomplished simply by substituting for the ordinary stopcock a three-way tap.

The whole arrangement becomes at once intelligible by a glance at the woodcut, which represents the burner half size.

A is the loaded foot, into which the elbow union-piece, B, is screwed. One end of this union is connected with a flexible pipe, not shown in the drawing; to the other screws the three-way stopcock, C. The plug, D, has only one orifice, and, when turned in a vertical direction, supplies the argand burner through the perforation, E. Into the side of the stopcock is soldered a small pipe, F, having a bore of about one-eighth of an inch. This is prolonged to the distance of one-tenth of an inch above the top of the argand burner, where it is brazed to a small support for the blowpipe, not represented in the drawing.

When the plug, D, is turned in a horizontal direction, the gas is shut off from both jets, but when turned in an inclined position, may be made to supply both jets at once, or either alternately. By this contrivance, either of the jets will be lighted before the other is extinguished.

In order that the jet may be likewise used for heating larger apparatus, there is a support, G, on which may be fixed a copper chimney, either plain or provided with the wire-gauze for producing the air flame.

ANALYSIS OF COAL-GAS.—The accurate analysis of gaseous mixtures—says Dr. FRANKLAND, in an able paper published in *Clegg's Treatise on Coal-Gas*, from which the following method is extracted—is one of the most delicate operations of modern chemistry. This arises not only from the difficulty of preserving gases, during the requisite manipulation, free from admixture with atmospheric air; but also from the circumstance, that their volume, the measurement of which is, in most cases, the only means of estimating their quantity, is liable to constant and considerable change, by fluctuations of temperature and of the pressure of the atmosphere, as well as by the dryness or humidity of the gas itself. This branch of chemical analysis owes much of its present accuracy and perfection to the admirable researches of Professor BUNSEN of Heidelberg.

All analytical operations upon gases must be conducted over mercury, which metal should be placed in a small wooden pneumatic trough, with plate-glass sides. The eudiometers, or measuring tubes, should be accurately calibrated and graduated into cubic inches and their tenths, the latter being subdivided by the eye into hundredths, when the volume of a gas is read off: such a division is readily attained by a little practice. At each determination of volume, it is necessary that the gas should either be perfectly dry, or quite saturated with moisture. The first condition is attained by placing in the gas for half an hour, a small ball of fixed chloride of calcium, attached to a platinum wire; the second, by introducing a minute drop of water into the head of the eudiometer before filling it with quicksilver. The determinations of volume must either be made when the quicksilver is at the same level inside and outside the eudiometer; or, as is more frequently done, the difference of level must be accurately measured in the subsequent reduction to a standard pressure. The height of the barometer, and the temperature of the surrounding atmosphere, must also be observed each time the volume of gas is measured, and proper corrections made for pressure, temperature, and also the tension of aqueous vapor, if the gas be moist.

The process of analysis described below has reference to purified coal-gas; the method of detecting the principal impurities being given in a former page.

1. *Estimation of Carbonic Acid.*—A few cubic inches of the gas are passed into a short eudiometer, moistened as above described; the volume is accurately noted with the proper corrections, and a bullet of caustic potassa is then passed up through the mercury into the gas, and allowed to remain for at least an hour; the volume of the gas being ascertained and deducted from the first volume, gives the amount of carbonic acid which has been absorbed by the potassa. Bullets of caustic potassa, or of any other fusible substance, should be of the size of a large pea, and may be prepared by melting the materials in a crucible, and then pouring them into a small bullet-mould, in which the curved end of a fine platinum wire has been placed. The ball attached to the wire is easily removed when cold.

2. *Estimation of Oxygen.*—Liebig has devised very accurate means for the estimation of this element, depending upon its rapid absorption by an alkaline solution of pyrogallic acid. To apply this menstruum, a small test-tube is filled with mercury and inverted in the trough: first, a few drops of pyrogallic acid, and then a similar quantity of *aqua potassæ*, are introduced into this tube by means of a pipette; a coke bullet—made by filling a bullet-mould containing a platinum wire with a mixture of two parts of coke and one of coal, both finely powdered, and then exposing the mould and its contents to a heat gradually increased to redness for fifteen minutes—attached to a platinum wire, is introduced into this liquid, and allowed to become saturated; it is then withdrawn, and conveyed carefully below the surface of the mercury into the eudiometer containing the residual gas of the first determination. Every trace of oxygen will be absorbed in a few minutes, and the volume being again measured, tho diminution from the last reading will represent the amount of oxygen originally present in the gas. It is essential that the coke-bullet, after saturation with the alkaline solution of pyrogallic acid, should not come into contact with the air before its introduction into the gas.

3. *Estimation of the Luminiferous Constituents.*—Various methods have been employed for the estimation of the so-called olefiant gas—luminiferous constituents—in coal-gas. That which has been most generally employed depends upon the property which is possessed by olefiant gas and most hydrocarbons, of combining with chlorine, which causes their condensation to the stato of an oily liquid. Hydrogen and light carbide of hydrogen are both acted upon in a similar manner, when a ray, even of diffused light, is allowed to have access to the mixture; but the condensation of olefiant gas and hydrocarbons takes place in perfect darkness, and advantage is, therefore, taken of this reaction to observe the amount of condensation which takes place when the mixture is excluded from light; the volume which disappears during this action of the chlorine being regarded as indicative of the quantity of olefiant gas present in the mixture. There are many sources of error inseparably connected with this method of operating, which render the results unworthy of the slightest confidence. The same remark will equally apply to the employment of bromine in the place of chlorine. In addition to the circumstance that these determinations must be made over water, which allows a constant diffusion of atmospheric air into the gas, and *vice versâ*, there is also formed in each case a volatile liquid, the tension of the vapor of which augments the volume of the residual gas, and this increase admits of neither calculation nor determination.

The only material by which the estimation of the luminiferous constituents can be accurately effected, is anhydrous sulphuric acid, which immediately condenses the hydrocarbons, but has no action upon the other ingredients, even when exposed to sunlight. The estimation is conducted as follows:—A coke bullet, prepared as described above, and attached to a platinum wire, being rendered thoroughly dry by gently heating it for a few minutes, is quickly immersed in *a saturated solution of anhydrous sulphuric acid*, and allowed to remain for one minute; it is then withdrawn, leaving as little acid adhering to it as possible, quickly plunged beneath the mercury in the trough, and introduced into the same portion of dry gas from which the carbonic acid and oxygen have been withdrawn. Here it is allowed to rest for about two hours, in order to insure the complete absorption of every trace of carbide of hydrogen. The residual volume of the gas cannot, however, yet be determined, owing to the presence of some sulphurous acid derived from the decomposition of a portion of the sulphuric acid. This is absorbed in a few minutes by the introduction of a moist ball of binoxide of manganese, which may be readily made by converting the finely-powdered binoxide into a stiff paste with water, rolling it into a globular shape, and then inserting a bent platinum wire in such a manner as to prevent its being readily withdrawn; the ball being gradually dried, it will become hard, and possess considerable cohesion, even after being moistened with water, previous to its introduction into the gas. After half an hour the manganese bullet may be withdrawn, and replaced by one of caustic potassa, to remove the aqueous vapor introduced with the previous one: in half an hour this bullet can be removed, and the volume of the gas at once noted. The difference between this and the previous reading gives the volume of the luminiferous constituents of the gas. This method is very accurate; according to its author, Dr. Frankland, the per centage of luminiferous constituents seldom varies, in two analyses of the same gas, more than ·01 or ·02.

4. *Estimation of the Non-luminous Constituents.*—These are, light carbide of hydrogen, hydrogen, carbonic oxide, and nitrogen. Their per centages are ascertained in a graduated eudiometer, about two feet in length, and three-fourths of an inch internal diameter, the thickness of the glass being not more than one-tenth of an inch. This eudiometer is furnished, at its closed end, with two platinum wires fused into the glass, for the transmission of the electric spark. A drop of water, about the size of a pin's head, is introduced into the upper part of the eudiometer before it is filled with quicksilver, and inverted in the mercurial trough; this

small quantity of water serves to saturate with aqueous vapor the gases subsequently introduced. About a cubic inch of the residual gas from the last determination is passed into the endiometer, and its volume accurately read off; about four cubic inches of pure oxygen are now introduced, and the volume—moist—again noted. The oxygen is best prepared at the moment when it is wanted, by heating, over a spirit or gas flame, a little chlorate of potassa in a very small glass retort, allowing sufficient time for every trace of atmospheric air to be expelled from the retort before passing the gas into the eudiometer. The open end of the latter must now be pressed firmly upon a thick piece of caoutchouc placed at the bottom of the trough, and an electric spark passed through the mixture. If the above proportions have been observed, the explosion will be but slight, which is essential if nitrogen be in the mixture, as this element will otherwise be partially converted into nitric acid, the results being thus vitiated. By using a large excess of oxygen, all danger of the bursting of the eudiometer by the force of the explosion is also avoided. The volume after explosion being again determined, a bullet of caustic potassa is introduced into the gas, and allowed to remain so long as any diminution of volume takes place. This bullet absorbs the carbonic acid produced by the combustion of the light carbide of hydrogen and carbonic oxide, and also renders the residual gas perfectly dry; the volume noted after this absorption, when deducted from the previous one, gives the volume of carbonic acid generated by the combustion of the gas.

The residual gas now contains only nitrogen, and the excess of oxygen employed.

The former is determined by first ascertaining the amount of oxygen present, and then deducting that number from the volume of both gases; for this purpose, a quantity of dry hydrogen, at least three times as great as the residual gas, is introduced, and the bulk of the mixture determined; the explosion is then made as before, and the volume—moist—again recorded. One-third of the contraction caused by this combination represents the amount of oxygen, and the remainder, when this is deducted from the volume of residual gas, after absorption of carbonic acid, shows the quantity of nitrogen.

The behavior of the other three non-luminous gases on explosion with oxygen, enables the operator readily to find their respective amounts by three simple equations, founded upon the quantity of oxygen consumed, and the amount of carbonic acid generated by the three gases in question. Hydrogen consumes half its volume of oxygen, and generates *no* carbonic acid; light carbide of hydrogen unites with twice its volume of oxygen, and generates *its own volume* of carbonic acid; whilst carbonic oxide combines with half its volume of oxygen, causing the formation of *its own volume* of carbonic acid.

If, therefore, the volume of the mixed gases be represented by A; the amount of oxygen taken up, by B; and the quantity of the mixed gases generated, by C; and further, the volumes of hydrogen, light carbide of hydrogen, and carbonic oxide respectively, by x, y, and z, the following equations arise:—

$$\begin{aligned} x + y + z &= \mathrm{A} \\ \tfrac{1}{2}x + 2y + \tfrac{1}{2}z &= \mathrm{B} \\ y + z &= \mathrm{C} \end{aligned}$$

From which the annexed values for x, y, and z are derived:—

$$\begin{aligned} x &= \mathrm{A} - \mathrm{C} \\ y &= \frac{2\,\mathrm{B} - \mathrm{A}}{3} \\ z &= \mathrm{C} - \left(\frac{2\,\mathrm{B} - \mathrm{A}}{3}\right) \end{aligned}$$

5. *Estimation of the Value of the Luminous Constituents.*—The methods above given will show the respective quantities of all the constituents in any specimen of coal-gas; but analytical results afford no clue to its illuminating power; they give, it is true, the amount of illuminating hydrocarbons contained in a given volume of the gas, but it is evident, from what has already been said respecting the luminiferous powers of these hydrocarbons, that the greater the amount of carbon contained in a given volume, the greater will be the quantity of light produced on their combustion; and, therefore, as the number of volumes of carbon vapor contained in one volume of the mixed constituents, condensable by anhydrous sulphuric acid, has been found to vary from 2·54 to 4·36 volumes, it is clear that this amount of carbon vapor must be accurately determined for each specimen of gas, if it be desirable to ascertain the value of that gas as an illuminating agent. Fortunately, this is easily effected, for if the amount of carbonic acid generated by one hundred volumes of the gas in its original condition be ascertained, knowing from the preceding analytical processes the per centage of illuminating hydrocarbons, and also the amount of carbonic acid generated by the non-luminous gases, the operator has all the data for calculating the illuminating value of the gas. For this purpose a known volume—about a cubic inch—of the original gas is introduced into the explosion eudiometer, mixed with about five times its bulk of oxygen, the electric spark passed, and the amount of carbonic acid generated by the explosion ascertained, as before directed. If the per centage of hydrocarbons absorbed by anhydrous sulphuric acid be denoted by A; the volume of carbonic acid generated by one hundred volumes of the original gas, by B; the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas, by C; and the volume of carbonic acid generated by the combustion of the luminiferous compounds—hydrocarbons—by x, one has the following equation:—

$$x = \mathrm{C} - \mathrm{B};$$

and, therefore, the amount of carbonic acid generated by one volume of the hydrocarbons is represented by

$$\frac{\mathrm{C} - \mathrm{B}}{\mathrm{A}}.$$

But, as one volume of carbon vapor gives rise to a similar quantity of carbonic acid, this formula also expresses the amount of the former in one volume of the illuminating constituents. For the purpose of comparison, however, it is more convenient to represent the value of these hydrocarbons in their equivalent volume of olefiant gas, one volume of which contains two volumes of carbon vapor; for this purpose the last expression need only be changed to

$$\frac{C - B}{2A}$$

Thus, if a sample of gas contain ten per cent. of hydrocarbons, of which one volume contains three of carbon vapor, the quantity of olefiant gas to which this ten per cent. is equivalent will be fifteen.

The application of this method furnishes an exact chemical standard of comparison for the illuminating value of all descriptions of gas; and by a comparison of the arbitrary numbers thus obtained, with the practical results yielded by the same gases when tested by the photometer, much valuable and useful information is gained.

Estimation of the Specific Gravity of Gas.—Although the mere determination of the specific gravity of gases is of very little use as a test of their commercial value —unless the gas is to be used for aeronautic purposes —yet, as it is still much employed by gas engineers, and as such an estimation is occasionally useful for controlling the results of chemical analysis, a method by which such a determination may be made is here subjoined.

The specific gravity of gases should be taken in a room where there is no fire, and where the temperature is liable to little variation during the time occupied in the operations. The following apparatus is necessary: First, a thin glass globe, capable of holding at least two hundred cubic inches, and furnished with a brass cap and stopcock, so accurately fitted as to prevent all ingress of air when the globe is exhausted; secondly, a small exhausting syringe or air-pump, to which the globe can be screwed air-tight; thirdly, a balance capable of weighing to one-fiftieth of a grain, when loaded with a quarter of a pound in each pan; fourthly, a glass tube, eighteen inches long, and half an inch in diameter, filled with fragments of fused chloride of calcium, and closed at each end with a perforated cork, through which passes a glass tube, of such dimensions as to admit of adaptation by means of caoutchouc tubing at one end, to the exit pipe of a small gas-holder, and at the other, to the stopcock of the glass globe.

The process consists in ascertaining the weight of equal volumes of atmospheric air, and of the gas under examination, at the same temperature and pressure. This is accomplished by first exhausting the globe by means of the syringe or air-pump, and then accurately ascertaining its weight, care being taken to allow time for the globe to assume the same temperature as that of the air surrounding the balance. The globe should then be connected with one extremity of the chloride of calcium tube, by means of a piece of vulcanized caoutchouc tube, and the stopcock being then very slightly opened, the air passing through the chloride of calcium, and thus being thoroughly deprived of moisture, should be allowed slowly to fill the globe. The latter being detached from the desiccating tube, is replaced in the balance, where it should remain undisturbed for at least five minutes, when the stopcock is opened for a moment to equalize the pressure within and without, and the weight then accurately determined. The difference between the two determinations gives the weight of the air enclosed in the globe. The exsiccating tube should now be attached to the exit pipe of the gas-holder, and a stream of gas allowed to rush through it, until every trace of air has been expelled from the interstices of the chloride of calcium; the globe, again exhausted, is then to be attached to the other extremity of this tube, and the stopcock being slightly opened, as before, the gas, perfectly dried in traversing the fragments of chloride of calcium, is permitted slowly to fill the globe, which should, whilst still attached to the drying tube, be allowed to stand undisturbed for a few minutes near the balance, before the stopcock is finally closed and detached from the drying tube. The weight of the globe thus filled with gas is ascertained, and that of the exhausted globe being subtracted from it, the difference indicates the weight of the gas. The weight of equal volumes of gas and atmospheric air at the same temperature and pressure having now been ascertained, it only remains to divide the former by the latter to know the specific gravity of the gas. Thus, suppose the weight of the exhausted globe to be 2000 grains; that of the globe filled with dry air 2060, and with exsiccated gas 2040 grains; the weight of the volume of air equal to the contents of the globe would be sixty, and that of the same volume of gas forty grains: hence, 40 ÷ 60 = ·6666, the specific gravity of gas, air being taken as unity.

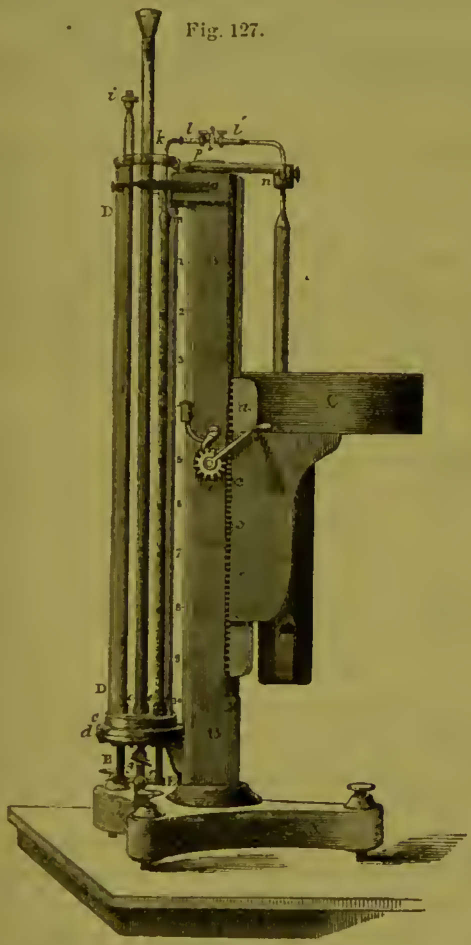
Unless a number of specific gravities are determined at the same time, it is indispensably necessary to ascertain the weight of the air contained in the globe previous to each determination. Care should be taken that the temperature of the room in which the balance is placed does not vary more than about one degree between the several weighings of the globe, as otherwise a considerable error will be introduced into the experiments. The globe should also be protected, as much as possible, from the heat radiating from the body of the operator during the several weighings.—*Clegg.*

Much time and space might be occupied in discussing the merits of the several apparatus to be employed in the analysis of gases, but this seems to the Editor to be quite unnecessary. The best plan will be to place before the reader the improved apparatus of FRANKLAND and WARD, which resembles that of REGNAULT and REISET in mechanical arrangement, although it differs entirely in the mode adopted for the measurement of the gaseous volumes.

The instrument, which is represented by the accompanying figure, consists of the tripod, A, furnished with the usual levelling screws, and carrying the vertical pillar, B B, to which is attached, on the one side, the movable gutta-percha mercury trough, C, with its rack and pinion, *a a*, and on the other the glass cylinder, D D, with its contents. This cylinder is thirty-six inches long, and four inches internal diameter; its lower extremity is firmly cemented into an iron collar, *c*, the under surface of which can be screwed perfectly watertight upon the bracket plate, *d*, by the interposition of a vulcanized caoutchouc ring. The circular iron plate, *d*, is perforated with three apertures, into which the caps, *e e e*, are screwed, and which communicate below the plate with the T-piece, E E. This latter is furnished with a double-way cock, *f*, and a single-way cock, *g*, by means of which the tubes cemented into the sockets, *e e e*, can be made to communicate with each other, or with the exit-pipe, *h*, at pleasure.

F G H are three glass tubes, which are firmly cemented into the caps, *eee*. F and H, which are only slightly shorter than the glass cylinder, are each from 15^{mm} to 20^{mm} internal diameter, and are selected of as nearly the same bore as possible, to avoid a difference of capillary action. The tube, G, is somewhat wider, and may be continued to any convenient height above the cylinder. H is accurately graduated with a millimetre scale, and is furnished at top with a small funnel, *i*, into the neck of which a glass stopper, about 2^{mm} in diameter, is carefully ground. The tube, F, terminates at its upper extremity in the capillary tube, *k*, which is carefully cemented into the small steel stopcock, *l*. F has also fused into it at *m* two platinum wires for the passage of the electric spark. After this tube has been firmly cemented into the cap, *e*, its internal volume is accurately divided into ten perfectly equal parts, which is effected without difficulty by first filling it with mercury from the supply-tube, G, up to its junction with the capillary attachment, and then allowing the mercury to run off through the nozzle, *h*, until the highest point of its convex surface stands at the division ten, previously made so as exactly to coincide with the zero of the millimetre scale on H; the weight of the mercury thus run off is carefully determined, and the tube is again filled as before, and divided into ten equal parts, by allowing the mercury to run off in successive tenths of the entire weight, and marking the height of the convexity after each abstraction of metal. By using the proper precautions with regard to temperature, *etcetera*, an exceedingly accurate calibration can in this way be accomplished.

Fig. 127.



The absorption tube, I, is supported by the clamp, *n*, and connected with the capillary tube, *k*, by the stopcock and junction-piece, *l'p*.

When the instrument is thus far complete, it is requisite to ascertain the height of each of the nine upper divisions on the tube above the lowest or tenth division. This is very accurately effected in a few minutes, by carefully levelling the instrument, filling the tube, G, with mercury, opening the cock, *l*, and the stoppered funnel, *i*, and placing the cock, *f*, in such a position as to cause the tubes, F H, to communicate with the supply-tube, G. On now slightly turning the cock, *g*, the mercury will slowly rise in each of the tubes, F and H; when its convex surface exactly coincides with the ninth division on F, the influx of metal is stopped, and its height in H accurately observed; as the tenth division on F corresponds with the zero of the scale upon H, it is obvious that the number thus read off is the height of the ninth division above that zero point. A similar observation for each of the other divisions upon F completes the instrument.

Before using the apparatus, the large cylinder, D D, is filled with water, and the internal walls of the tubes, F and H, are, once for all, moistened with distilled water, by the introduction of a few drops into each, through the stopcock, *l*, and the stoppered funnel, *i*. The three tubes being then placed in communication with each other, mercury is poured into G, until it rises into the cup, *i*, the stopper of which is then firmly closed. When the mercury begins to flow from *l*, that cock is also shut. The tubes F and H are now apparently filled with mercury, but a minute and imperceptible film of air still exists between the metal and glass; this is effectually got rid of by connecting F and H with the exit-tube, *h*, and permitting the mercury to flow out until a vacuum of several inches in length has been produced in both tubes. On allowing the instrument to remain thus for an hour, the whole of the film of air above-mentioned will diffuse itself into the vacuum, and will become visible as a minute bubble in each tube, on allowing the vacuum to be filled up from the supply-tube, G. These bubbles are, of course, easily expelled, on momentarily opening the cock, *l*, and stopper, *i*, whilst G is full of mercury. The absorption-tube, I, being then filled with quicksilver, and attached to *l* by the screw clamp, the instrument is ready for use.

In localities where a constant supply of water from street mains can be had, the temperature of the water in the cylinder, D D, can be maintained perfectly constant by allowing a continuous stream, direct from the main, to flow into the bottom of the cylinder, and make its exit near the top. By this arrangement it has been proved, in an extensive series of experiments, that the temperature of a cylinder supplied from the Manchester high-pressure mains varies so very little in twelve hours, that it scarcely requires correction in the most delicate experiments.

In illustration of the manner of using the apparatus, let one take as an example the analysis of atmospheric air. A few cubic inches of air freed from carbonic acid having been introduced into the tube, I, it is transferred into F for measurement by opening the cocks, *l l′*, and placing the tube, F, in communication with the exit-pipe, *h*; the transference can be assisted, if needful, by elevating the trough, C. When the air, followed by a few drops of mercury, has passed completely into F, the cock *l* is shut, and *f* turned, so as to connect F and H with *h*. Mercury is allowed to flow out until a vacuum of two or three inches in length is formed in H, and the metal in F is just below one of the divisions; the cock, *f*, is then reversed, and mercury very gradually admitted from G, until the highest point in F exactly corresponds with one of the divisions upon that tube; suppose it to be the sixth division. This adjustment of mercury, and the subsequent readings, can be very accurately made by means of a small horizontal telescope, placed at a distance of about six feet from the cylinder, and sliding upon a vertical rod. The height of the mercury in H must now be accurately determined, and if, from the number thus read off, the height of the sixth division above the zero of the scale on H be deducted, the remainder will express the true volume of the gas; but, in order to compare this with subsequent readings, made at other divisions upon F, the number thus obtained, which evidently represents the pressure of the gas, is reduced to what it would have been had the gas been expanded to the tenth division of F. Bearing in mind that the pressure of a gas is inversely as its volume, this reduction is very simply effected by multiplying the number as above obtained by six-tenths, or 0·6; and, in all cases, any determination of pressure made at any division upon F may be reduced to the pressure of the same volume when expanded to the tenth division, by the use of a fractional multiplier, the denominator of which is ten, and the numerator, the number of the division at which the determination is made.

As the temperature is maintained constant during the entire experiment, no correction on that score has to be made; the atmospheric pressure being altogether excluded from exerting any influence upon the volumes or pressures, no barometrical observations are requisite, and, as the tension of aqueous vapor in F is exactly balanced by that in H, the instrument is, in this respect, self-correcting.

Hydrogen being then introduced in the same way as the original gas, and the volume determined anew, the electric spark is passed through the mixture by means of the platinum wires at *m*, and the determination of the contraction caused by the explosion terminates the process. The following are the results of an analysis of air made in this way:—

VOLUME OF AIR USED.

(Determination at fifth division on F.)

Observed height of mercury in H,		673·0 mm
Height of fifth division above zero,		383·0 "
Corrected pressure of gas,	=	290·0 "
		·5 "
Corrected pressure of gas at tenth division,	=	145·00 "

VOLUME AFTER ADMISSION OF HYDROGEN.

(Determined at sixth division.)

Observed height of mercury in H		772·3 mm
Height of sixth division above zero,		304·0 "
Corrected pressure of gas,	=	468·3 "
		·6 "
Corrected pressure of gas at tenth division,	=	280·98 "

VOLUME AFTER EXPLOSION.

(Determined at fifth division.)

Observed height of mercury in H,		763·3 mm
Height of fifth division above zero,		383·0 "
Corrected pressure of gas,		380·3 "
		·5 "
Corrected pressure of gas at tenth division,	=	190·15 "

RESULTS.

Volume of air used,	145·000
Volume of oxygen,	30·276

Hence:

Nitrogen,	79·120
Oxygen,	20·880
	100·000

Subjoined are the results of a series of analyses performed upon the same specimen of atmospheric air, previously freed from carbonic acid by caustic potassa, which show the delicacy of the indications of this instrument:—

	I.	II.	III.
Oxygen,	20·880	20·888	20·883
Nitrogen,	79·120	79·113	79·117
	100·000	100·000	100·000

	IV.	V.	VI.
Oxygen,	20·867	20·868	20·776
Nitrogen,	79·133	79·132	79·124
	100·000	100·000	100·000

Basford's Patent Method of Purifying Gas.—**Basford** obtained a patent in 1855 for purifying gas, by passing it through heated charcoal, previously impregnated with lime-water.

Wood charcoal is preferred, and this is immersed in a saturated aqueous solution of lime, for not less than fifteen minutes, after which it is termed by the patentee *prepared charcoal*. The apparatus in which this is heated, and in which the gas passes over the charcoal, is of cast-iron, and is represented in Figs. 128, 129, and 130. It is divided into separate compartments, A A, by partitions alternately fixed and loose, the former being shown by B, while the latter are indicated by C. Figs. 129 and 130 exhibit these more in detail. Each fixed partition has an opening—Fig. 130—at the bottom,

Fig. 128

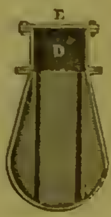
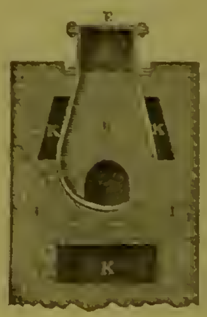
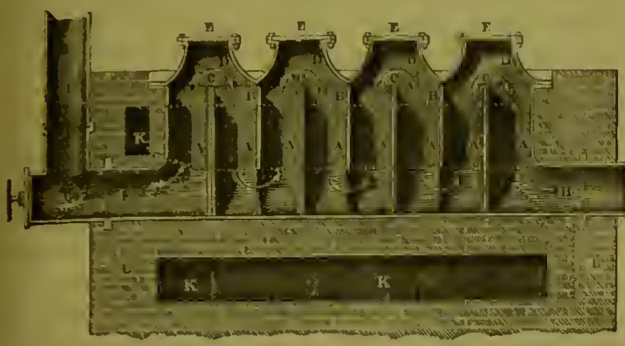


Fig. 129



while those which are movable are open at the top, so that the gas can be made to pass alternately up and down the several chambers, *over* the *loose*, and *under* the *fixed* diaphragms. Open covers to the compartments are indicated at D, and are closed by lids or plates, E. To one end of the apparatus is attached a D-shaped flanged pipe, F, into which the pipes leading from the retorts are fixed, either vertically by the pipe I, or horizontally by the mouth-piece G, as may be required. The outlet pipe of the apparatus, by the hydraulic main, and thence to the gas-holder, is seen at H. K K are flues, by means of which heat is applied, and L L designates the brickwork in which the whole apparatus is set.

Fig. 130.



On the gas passing through the heated prepared charcoal, it is freed from a large amount of foreign compounds, partly by chemical, partly by mechanical action, and deposits a residuum, which possesses the properties of, and may be used as, a pigment. The gas thus purified has a much greater illuminating power than that submitted to the ordinary process of depuration.

The claim of the patentee is—1. For the separation of the impurities from coal-gas, by passing it through charcoal saturated with lime-water, and heated as described; and, 2. For the formation of a residuum, or deposit, derived from the gas, which may be used as a pigment, or color.

For the removal of the ammonia and the sulphide of hydrogen by one and the same process, a new method of purification has been adopted, and is one well worthy of confidence. The screens of the purifiers are covered with a mixture of carbonate of lime and sulphate of iron, which, subsequently exposed to the air, become carbonate of iron and sulphate of lime; and by the absorption of oxygen, the carbonate of iron leaves its carbon, and becomes partly sesquioxide of iron. The gas, streaming through this mixture—sesquioxide of iron and sulphate of lime—gives up its sulphide of hydrogen to the oxide of iron, forming sulphide of iron and water, while the carbonate of ammonia—contained also in the impure gas—decomposing the lime-salt, forms sulphate of ammonia and carbonate of lime.

When the purification is completed, and the mixture has done its work, it is exposed to the air, and the sulphide of iron absorbing oxygen, is converted into a basic sulphate of iron. Hence, the same mixture as at first is obtained, namely, carbonate of iron and sulphate of lime, with the addition of sulphate of ammonia, which may be washed out and preserved, while the residue is employed over and over again. By this elegant process, the noxious sulphur compounds are utilized in the fabrication of sulphate of ammonia, and the mixture seems never weary of performing its duty; hence, not only is the februlation performed at one process, but the noxious ingredients are converted into compounds of much value.

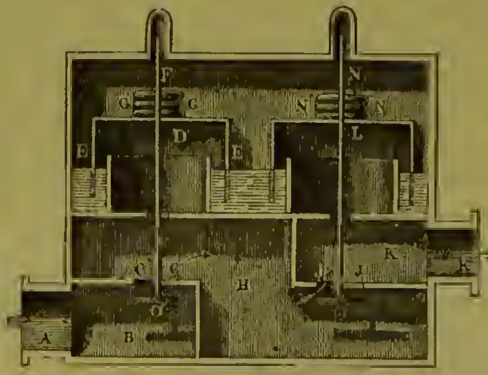
Another method of removing ammonia may be noticed: it consists in spreading on the screens superphosphate of lime, consisting of bones decomposed by sulphuric acid; the addition of ammonia to this, makes it a powerful and excellent manure.—*Clegg.*

CHISHOLM'S METHOD.—CHISHOLM'S method for the purification of gas consists in combining or mixing together the peculiar red earthy or ochry-looking substances found mingled with peat and the subsoil of peat, with hydrate of lime, or the mixed hydrates of lime and magnesia obtained from magnesian limestones, and their combination or mixture. He then introduces into the vessel, known to gas-makers as the dry-gas purifier, this mixture, and the foul gas passes through it until it is rendered pure; such purity being ascertained by the application of the tests usually employed by makers of gas for that purpose. The red earthy or ochry substance above alluded to, is composed chiefly of the oxides and salts of iron and manganese, and it is principally to these metallic matters that the purifying agency of the compounds is due; therefore, the greater the quantity of these oxides this earthy matter contains, the better is it adapted to the purpose for which the patentee uses it; and although the exact proportion of lime to be added is not material, yet the greater the amount of metallic matters there may be contained in the red or ochry earthy matters aforesaid, the more lime, or lime and magnesia, must be used; for every three parts by weight of metallic matters in this earthy matter, one part of lime by weight is preferred. Instead of the above red earthy matter, there are sometimes employed in the same way and proportion, the fine red sandy gravel so general around London in the neighborhood of chalk beds, or the red clay which is so common around Rugeley and other districts, or the phosphate or subphosphate of iron, known by these names to all geologists, and common in many boggy districts. All these, or any of them, he uses precisely in the way or combination described with respect to red earthy peat matters already alluded to; and he adds, that when these substances or mixtures, or any of them, have ceased to purify the gas from sulphide of hydrogen and other impurities, their powers may be again in part or altogether renewed or restored by passing or forcing through them a current of air, or by merely exposing them to the atmosphere, after which they may be used over and over again, or many times in succession.

POOLE'S PATENT.—POOLE took out a patent for improvements in regulating the flow and pressure of gas and other fluids. He remarks, that it is often desirable to deliver aeriform fluids at a certain uniform pressure, and various means have before been resorted to for effecting this object; accordingly his invention consists of combining the use of two or more governors or regulators, which, acting independently and in succession, are alleged to accomplish the desired object more completely than has been done heretofore. The description of governors or regulators which are preferred for this purpose, are those where inverted vessels are used, working in quicksilver or other fluid, and connected to the induction valves. Supposing the apparatus to be arranged for regulating the supply of gas or other aeriform fluid, the main or supply pipe, where the regulation is to take place, is arranged to communicate in succession with two or more chambers, each having a governor or regulator, and so that no gas can pass from the main or supply-pipe to the furthermost chamber, without having passed through, and been regulated more or less perfectly by, the previous regulators or governors; by which means the gas, supposing it to come up to the first governor or regulator at a pressure exceeding that at which it is desired to deliver it at, will act on the governor, and tends to close the valve, and thereby restrict the passage of the gas into the first chamber; the gas then passes from the first chamber or governor into the second, and, if it be still at an excessive pressure, it will be again retarded in its passage, and so on, according to the number of governors or regulators combined and caused to act in succession.

Fig. 131 shows a vertical section of an apparatus combined according to this patent, having two regulators or governors acting in succession; but other apparatus may be made with more than two, to act in succession in a similar manner. The form of regulator or governor preferred, is that where an inverted vessel is employed fixed to the valve, the action of which is to be regulated; but the form of the parts may be varied, so long as two or more regulators or governors are combined to act in succession. No claim, however, is made to the governors or regulators separately, when two or more are not combined to act on and regulate the same supply. A is the inlet for the gas or aeriform fluid; B is a chamber, the opening, C C, out of which is capable of being more or less closed by the valve, O, which is on the stem, F, to which the inverted vessel D is fixed, the edges of which dip into mercury or other suitable fluid at E E; there being weights, G G, on the vessel D, according to the degree of pressure it is desired to regulate or bring the supply of gas or other aeriform fluid to, when it passes away at the outlet, K. The gas or other aeriform fluid coming into the chamber, B—above the desired pressure—will, to some extent, be regulated by its acting on the first regulator by raising the vessel, D, which will also raise the valve, O, in the compartment, B, towards the opening, C C, till the quantity of the gas allowed to pass into the chamber, H, of the apparatus will be brought to nearly the desired pressure. The gas or aeriform fluid in the chamber, H, passes through the opening, J J, into the compartment, K, and acts on the inverted vessel, L, which is affixed to the stem, N, by which the valve, O, in the chamber, H, will be more or less closed, according as the pressure of the gas or aeriform fluid in the chamber, H, is more or less in excess of the pressure at which it is desired the gas or aeriform fluid should go off at the outlet, K. It would be well to state, that usually the same amount of pressure or weight, N N, is applied to the inverted vessel L, as there is by the weights, G G, to the vessel D, such being believed to be the best mode of working when using such apparatus. The vessel L, like the vessel D, dips into mercury or other liquid at its lower edges. By using a succession of regulators or governors, any want of correctness of the regulation of the first will be compensated for by the succeeding ones.

Fig. 131.



MICHAEL'S PATENT.—GEORGE MICHAEL, who has also taken out a patent for improvement in the manufacture of gas, remarks in his specification, that in the present state of progress in the different arts which cooperate together in the construction of gas-works, he thinks the power of the manufacturer may be increased, and the gas produced more economically than by the present mode, without employing large numbers of fine strong men to destroy their health, by charging red-hot retorts, through very narrow apertures, with small quantities of coal, and to perspire during twelve hours in front of an intolerably hot radiating surface. He proposes to substitute for the sinews of these men the action of steam-power; and, with this intention, he amplifies considerably the usual dimensions of a retort, in order to obtain in one distilling apparatus as much, if not more, heated surface as is now to be found in a whole bed of sixteen retorts twenty feet long; this he does for the purpose of having the floors of huge retorts all upon one and the same level, in order that the same steam apparatus used for charging and drawing one of them may perform the same operation for the others, by simply moving such apparatus upon rails in front of the retorts.

The dimensions in the clear which he prefers giving to these huge retorts are thirty feet in length, two feet in height, and about nine feet in width, the top being parallel to the floor, so that the transverse section of the interior of the retorts represents an elongated rectangular figure. These retorts are built with fire-bricks; but he observes, that if he only cemented the bricks together with fire-clay, as is usually done, the working of the retort would depend on the regular action of the exhauster—that is to say, that should the exhauster cease to work, the gas would pass through the joints of the bricks, an occurrence which would place a gas-work in jeopardy. To meet this great difficulty, the bricks of which the retort is made are laid in a vitreous cement, which, when subjected to the heat necessary for making gas from coal, forms a glaze, and renders the retort impermeable to gas. The best way to prepare this compound is, to pound and carefully mix together a double, treble, or a more compound fusible silicate, in which silica, lime, potassa, soda, magnesia, oxide of iron, oxide of manganese, or biborate of soda, may be usefully employed; but should local circumstances not admit of this, the good effect produced by potassa, soda, or better, biborate of soda, in the composition of the cement intended to become vitrified, must not be lost sight of. It is evident that this cement must be formed into a paste with a small quantity of water, so as to be easily used by the bricklayer.

It will be obvious to all practically acquainted with the manufacture of porcelain, earthenware, or glass, that the idea of setting the bricks of the retorts in a vitreous cement can be carried out in an infinity of different ways, according to localities, giving in each place the preference to the cheapest of the articles here above noticed. For instance, in London, and in many other towns, recourse can at once be had to a compound silicate, which is a refuse from the glass paper manufactories—namely, the glass dust—to which an addition of two per cent. or more of manganese, and four per cent. or more of borax, can be made to facilitate the fusion of the aforesaid glass dust. In other places it may be cheaper to employ potassa or soda as a cement between the bricks, the silica and alumina of the fire-bricks, when heated, combining with the alkali and forming a vitreous glazing cement, and so on in a variety of other ways.

MICHAEL'S huge retort is furnished at each end with a cast-iron mouth-piece plate, contrived for receiving a luted lid, which is firmly secured by cotters. This retort is provided with two or more orifices at the top, by which the charge of coal is introduced by tilting waggons running on proper railways; the coal so introduced into the retort is then spread equally over the bottom by the aid of a rake, which forms the head of a rack worked by a steam-engine. The charge of coal preferred to work off in such a large retort is six tons, forming a layer of ten inches deep. When the charge is worked off, the mouth-pieces are to be opened by unfastening and hoisting the lids, and the charge of coke is pushed out in one cake by the assistance of the steam-rack, the head or rake of which being for this purpose turned upside down, so as to act with its head and not with its teeth. Such coke, if it be desired, may be received in an oven capable of being closed, and there treated with this intention by the admission of air and an injection of steam, leaving one opening for abducting the products. One great peculiarity in the construction of these huge retorts is, that they are well isolated from contact with any of those parts of the construction which are liable to cool, either by radiation or by contact with the soil; this isolation is obtained by preserving round the retorts a circumambient empty space, in which the products of the combustion in the fire-places are caused to decant their heat at different stages in their perambulation, before finally passing under the immediate foundation of the retort on their way to the main flue, which is constructed outside the foundations of the retorts, or nearly so.

Fig. 132.

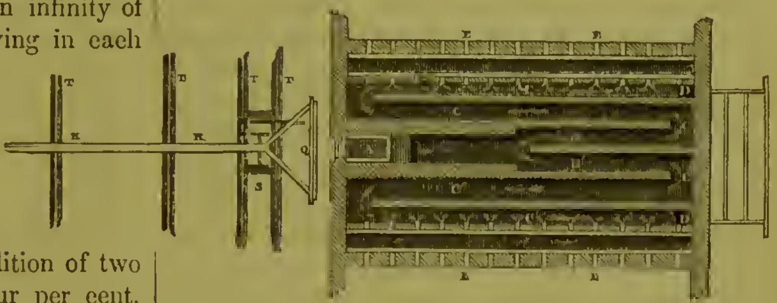
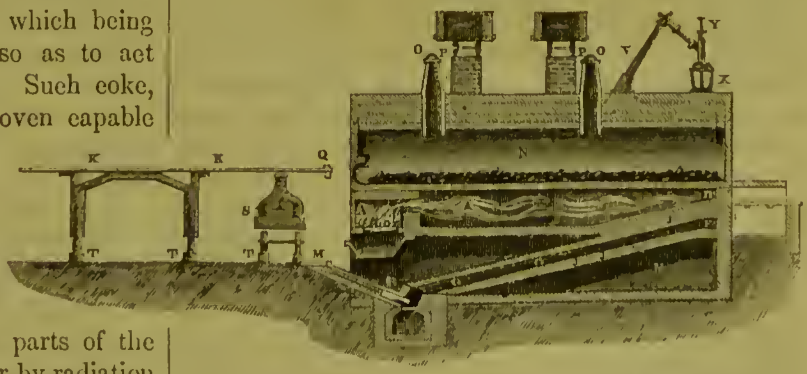


Fig. 133.



The patentee then proceeds with the technical description of the construction of a retort, such as that referred to in the drawings—Figs. 132 and 133. The products of combustion, on leaving the fireplace, divide into two parts, at B and B′; one follows the course, B, C C C, till arriving at the vertical flue, D, through which it descends into the chamber, F, which is common to these, and to those products of the combustion which have followed the course, B′, C′ C′ C′, D′. During such course, the products of combustion emit part of their heat from the orifices, E E E E, through which they ascend round the retort, so that in reality, by this phenomenon of decantation, there are formed two inverse currents on the sides of the retort, the hottest ascending, which, after having parted with a portion of its heat, will become descending; and the constant repetition of these effects will have for result the keeping of the sides and top of the retort at the same temperature as its floor or bottom. The drawings show distinctly how the under floor, the sides, and the top of the retort are constructed, for allowing this phenomenon of decantation of heat to produce its full effect everywhere round the retort. Particular stress is laid on this system of construction, which offers every possible facility to the working out of that law of nature, according to which the hotter parts of the gaseous products have a tendency to rise, and the colder to descend. It is according to the same principle that the products of combustion left in the chamber, F, are caused to descend along an inclined plane in the six flues, G G, before entering the lower chamber, H, which delivers them through one aperture to the horizontal chimney, I. The orifice last spoken of is commanded by the damper, K, which regulates the draught of the fireplace. This damper is worked in an inclined flue, the entrance of which is to be covered by the tile, M, in front of the retort. The six inclined flues leading to the chamber, H, are connected together sideways by the openings, J J.

The under floor of the retort is composed of three parts, differing one from another in their construction—that is to say, the floor of the retort, which is formed by bricks on edge, is separated from the fire-place by an arch of nine inches thickness, from the subsequent main flue by an arch of four inches and a half, and from all the divided flues by flat bricks two inches and a half thick, and eight inches long, laid in six parallel rows, the joints of such rows corresponding to the centre line of five rows of pillars.

Charging and Drawing of Retorts.—The interior of retort, N, receives the charge of coal through the openings, O O, which are shut by luted caps, P P, movable at will; the coal is brought to the retort-house in trucks, so arranged that when tilting their contents fall at once into a movable funnel placed for the time being in the openings, O; these dispositions are required for charging the retort quickly; and, when well adapted, as indicated in the accompanying drawings, the retort can receive its charge of six tons of coal in less than six minutes, provided that the coal be spread at the rate it falls down by proper mechanical power. The apparatus to which preference is given for producing this effect is composed of a cast-iron rake, Q, which forms the head of a rack sliding in a cast-iron frame, K K; this receives its motion from a steam-engine, S, fitted to the frame; the motion is transmitted by the ordinary mechanical contrivances. In order that the same steam apparatus may be rendered serviceable for the working of twenty-four retorts, or more, the frame here spoken of rests upon a system of wheels, T T, rolling upon rails parallel to the front of the retorts. The steam is adducted by a pipe which runs in a casement surrounded by sand or other non-conductor, the full length of the beds of retorts; this pipe is provided with small outlet branches and cocks between each two retorts, for the purpose of delivering the steam to the engine of the steam-power rake, through a movable connecting pipe. When the gas is worked off, and the charge is ready to be withdrawn, the lids of the retorts are moved, and the coke is pushed out of the retort in one lump by the action of the steam-rake, the head of which—namely, the rake—is for that purpose turned upside down by swivelling it round a collar. By this contrivance the teeth of the rake are spared, and its head, which is shaped like a strong rib, performs the work of clearing the retort. It is well to observe, that, in order to prevent the teeth or the rib of the rake wearing out the brickwork, they are kept at half an inch distance from the floor or bottom of the retort by friction rollers, suitably placed for bearing the weight of the apparatus. There are also friction rollers fitted on the sides of the rake for guiding its movement along the sides of the retort.

When the retort is at work, the gas passes off through the ascension pipe, V, and enters the hydraulic main, X, through the plunger, Y, which is suspended to a screw, and can be moved up and down for the purpose of transforming at pleasure the hydraulic main into a dry main by suppressing the dip, which contrivance is very valuable for relieving the retorts from all pressure.

Mr. Alexander Croll has taken out a patent for freeing gas from its ammonia, and a part of the sulphide of hydrogen, producing at the same time chloride of ammonium. He introduces a solution of the chloride of zinc into a vessel, upon the same construction as a wet lime purifier; on admitting the gas, double decomposition ensues; an insoluble sulphide of zinc, and a solution of chloride of ammonium, are produced. The gas must be further purified with lime in the usual way.

The specifications of a great number of other patents for alleged improvements in gas-making might be given: but as they are not of much interest, and probably of too little usefulness ever to be adopted, the Editor deems it unnecessary further to allude to them, which would only exhaust the patience of the reader with a series of dry details. In conclusion, the Editor has to express his thanks for the courtesy and information rendered to him by Mr. Samuel Edwards, formerly of the Liverpool Gas Works.

GELATIN.—*Gélatine*, French; *Gallerte*, German: *Gelatin*, Latin.—Skin, the tissue of bones, cartilage, and many analogous animal tissues, possess the well-known property of yielding to boiling water a substance capable of becoming jellied by the cooling of the menstruum. This was for a long time regarded as a peculiar organic principle, and was known by the name of *gelatin;* but, latterly, Muller found it to consist of gelatin, properly so called, and of another particular product, which he denominated *chondrin*. It is generally assumed, though not perhaps on very sufficient grounds, as Brande remarks, that the gelatinous textures do not contain ready-formed gelatin, that that substance does not, in fact, pre-exist in the animal kingdom, but that it is generated by the action of hot water upon the membranous tissues.

The historical information connected with this subject is very limited. *Ichthyocalla*—the Latin synonym for *isinglass*, derived from two Greek words, signifying *the glue of fish*—is repeatedly mentioned by Dioscorides and Pliny; the latter writer attributes the discovery of it to Dædalus.

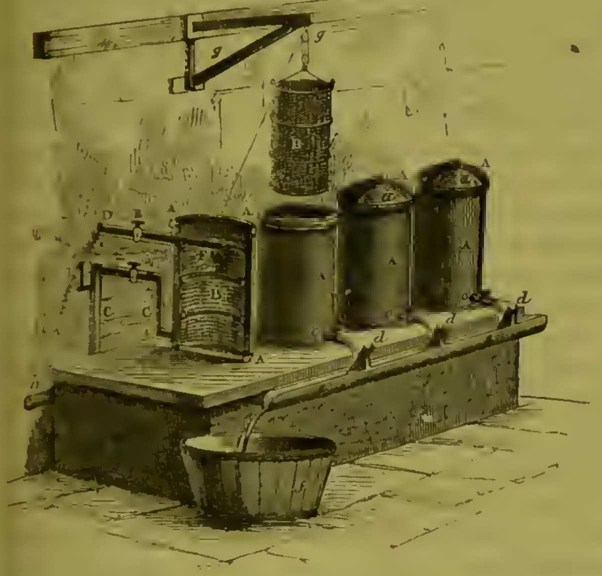
Preparation.—Gelatin is obtained by subjecting fragments of hoofs, horns, hides, bones, the feet of calves, cows, sheep, *et cetera*, to the action of boiling water or steam. The resulting menstruum is skimmed and strained, so as to effect the removal of floating fatty bodies, and of any deposit which might be formed; then allowed to gelatinize by spontaneous decrease of its temperature.

It may also be procured from shavings of hartshorn, the product being tasteless, and having the advantage of being entirely free from fatty and oleaginous matters.

When gelatin is used as an article of food, the material should be of the best description, and quite fresh. Bones intended for this purpose ought to be well preserved in brine, or to be dried in a stove. Their gelatin is best extracted by the combined action of steam and a current of water percolating the fragments. Cast-iron cylinders are generally used in this part of the process. A vertical section of one of these is represented in Fig. 134, where A A A show the exterior cylinders, containing a basket or cage, B, filled with bruised bones; C C the pipe conveying steam to the interior; D, a pipe for the introduction of water, provided with a stopcock, E, for regulating the quantity of the supply, and to which is accurately fitted a tube of tinplate, F, closed at the inside end, and perforated on its under side with small holes, so as to allow of the percolation of the water: this tube is inserted in its proper place after the bone-cage has been introduced.

The cylinders, represented by A A A A, are elevated about twenty inches from the floor, and secured in their respective positions by screws; *a a* are the lids, in which are tubulures or valves; a thermometer is placed at *b;* the stopcocks, for withdrawing the gelatinous menstruum, are shown at *c c; d d* are small gutters of tinplate; *e e*, the main conduit of discharge into the cistern, *f; g g*, blocks and tackle for raising the bone-basket; *h*, the main steam-pipe.

Fig. 134.



When a pure jelly is required, the cylinder, after being charged with bones, is wrapped in a strong, coarse woollen material; as soon as the fatty matters cease to flow, the stopcock, E, which admits the cold water, is closed, as also those at the bottom of the cylinders, *c c c*, which are to be opened only at the end of every hour, but to such an extent only as to let the gelatinous solution run out, without allowing any steam to escape. The menstruum is subsequently strained, and poured into shallow vessels of tinplate, or upon slabs of marble, slate, or compact and polished stone, to solidify. It is finally cut into shreds, *et cetera,* as may be thought proper. This is, however, only one method of manufacturing gelatin; and others, for which patents have been obtained, will be given in a subsequent part of the present article.

PROPERTIES.—When *pure*, gelatin is colorless, transparent, hard, and endued with great but variable coherence, according to the kind of tissue from which it is obtained. It is inodorous and insipid. Its specific gravity is greater than that of water. It has a neutral reaction. When heated, it softens, diffuses a peculiar odor, enters into a state of semi-fusion, bends, tumefies, and then exhales the odor of burnt horn. In the air it takes fire with difficulty, smokes, flames only some instants, and leaves a bulky charcoal difficult to incinerate, the ashes of which consist principally of phosphate of lime. By dry distillation, gelatin gives much carbonate of ammonia, and yields in general the ordinary products of the distillation of nitrogenized substances.

In cold water it softens, intumesces, becomes opaque, but does not dissolve. A liquid which contains one-hundredth part of its weight of gelatin becomes viscous on cooling, but when it has only the one-hundred-and-fiftieth, the menstruum remains fluid. These phenomena, however, vary with the temperature. In winter the jelly is much more readily formed than in summer. If the solution of the gelatin is effected too quickly, the jelly obtained is less firm. Moreover, the result varies, not only in gelatin obtained from different tissues, but also with that obtained from the same tissue taken from animals of various ages.

It differs also according to the care which has been taken in the preparation of the gelatin; when its solution has been exposed to a temperature higher than 212°; and when it begins to sour, it loses in part the property of becoming jellied. The same happens when its solution is heated and cooled several times. If gelatin be left a long time in the open air, at a temperature of 60° to 68°, it becomes ammoniacal, and putrefies, diffusing a very fetid smell. The addition of a certain quantity of acetic acid prevents the putrefaction without destroying its adhesive power.

Gelatin is not sensibly soluble in alcohol, and when the latter is poured into its solution, lukewarm and somewhat concentrated, it coagulates in a white coherent, elastic, and slightly fibrous mass, which adheres to the vessel with much force. Like dry gelatin, it softens in cold water without dissolving in it. On evaporating the alcohol, there remains a thin transparent coating, very soluble in cold water, but which is not capable of being jellied. Common gelatin, in a dry state, treated with alcohol, gives up to it a certain quantity of fatty matter, and some substances of an extractive nature. It is perfectly insoluble in ether and in oils, both fat and volatile.

Gelatin, when in the jellied state, and treated with alcohol, undergoes a dehydration, under the influence of which it contracts much. It was by this means that GONNOR succeeded in remarkably reducing the size of a print obtained in a very hydrated film of gelatin, and transferring it, so reduced, to stone, from which he obtained a new impression, quite similar to the first, but more or less diminished.

By taking these prints, on the contrary, with gelatin very little hydrated, and afterwards steeping them in water, a dilatation of the plate is obtained, which enlarges the figures with the same regularity.

THENARD observed, that if chlorine be passed into a somewhat concentrated solution of gelatin, each bubble is surrounded with a white elastic matter, which follows it to the surface of the liquid, and which, at the moment when the bubble bursts, leaves a white glutinous matter, capable of taking a chatoyant appearance by malaxation. Only a small quantity of chlorine is required to precipitate all the gelatin, and, when this body is in excess, the deposit becomes of a light yellow, the liquor containing free hydrochloric acid, and only a very small quantity of animal matter remaining in solution. Gelatin, combined with chlorine, is insoluble in water and alcohol; it reacts as an acid, a property of which it may be deprived by macerating and washing it with tepid water. It exhales tho odor of chlorous acid, which it evolves when heated at 212°, a brownish residue remaining. MULDER states that it consists of one equivalent of gelatin $= C_{13} H_{10} O_5 N_2 + Cl_2 O_3$. When acted upon by ammonia, nitrogen is disengaged, chloride of ammonium formed, and unaltered gelatin separated. An opalescent, gelatinous body is simultaneously produced, the composition of which is represented by the last-mentioned chemist as three equivalents of gelatin $= 3 (C_{13} H_{10} O_5 N_2) + 2 (Cl_2 O_3)$. MULDER has also examined two additional chlorous compounds of gelatin, the first being $4 (C_{13} H_{10} O_5 N_2) + Cl_2 O_3$; the other, $5 (C_{13} H_{10} O_5 N_2) + 2 (Cl_2 O_3)$. Much doubt exists with regard to the correctness of these results. Iodine and bromine do not give rise to any synonymous combinations.

Concentrated sulphuric acid produces a very remarkable alteration in gelatin, converting it into *sugar of gelatin, leucin, et cetera*, which will be subsequently noticed.

Nitric acid, aided by heat, transforms gelatin into oxalic acid.

Concentrated acetic acid renders softened gelatin transparent, and then dissolves it; the solution does not become viscid, but preserves its adhesive property. Diluted acids, on the other hand, do not prevent gelatin giving a coagulum on cooling.

The alkalies when dilute, and even concentrated ammonia, do not deprive it of the property of becoming jellied, but render the solution turbid by causing a precipitate of phosphate of lime. Softened gelatin dissolves at the ordinary temperature in concentrated aqua potassæ, leaving a white residuum, which is composed principally of phosphate of lime. If the solution be exactly saturated with acetic acid, and evaporated, it does not become glutinous; the gelatin, altered and combined with acetate of potassa which remains after the evaporation, is soluble in alcohol. Sulphuric acid precipitates from this menstruum sulphate of potassa, combined with modified gelatin; and if the precipitate be dissolved in water, and the liquor left to spontaneous evaporation, it crystallizes to the last drop. The aqueous solution of the salt is abundantly precipitated by the infusion of nut-gall, by chloride of mercury, and by the sesquisulphate of iron. Hydrate of lime does not alter the solution of gelatin, which dissolves much of it. The same may be said of phosphate of lime; hence the reason why so large a quantity of this salt occurs in the glue of commerce. No subsidence is occasioned in dissolved gelatin by the addition of neutral sesquisulphate of iron, until the menstruum has been boiled, when a flocculent reddish-yellow precipitate falls, consisting, according to MULDER, of three equivalents of gelatin combined with six equivalents of oxide of iron, and one of sulphuric acid. DUMAS states that gelatinous menstrua are not thrown down either by the neutral or basic acetate of lead, but, according to GMELIN, the latter causes the formation of a copious subsidence. If a gelatinous menstruum be gradually mixed with a solution of chloride of mercury—corrosive sublimate—a cloudiness is produced which quickly disappears. This effect continues till a certain quantity of the reagent has been added, when the gelatin is at once precipitated as a white, coherent, and very elastic coagulum. The behavior of gelatin with nitrate and subnitrate of mercury is synonymous. Protochloride of tin causes a brown flocculent subsidence, but the bichloride gives no reaction.

Silver and gold salts do not precipitate gelatin, but by the influence of solar light a portion of the metal is reduced. It is thrown down by sulphate of platinum in brown viscous flakes, which blacken on the filter, and are afterwards easily pulverized. E. DAVY regards this salt as an infallible test for the detection of gelatin, even in the presence of albumen, and in solutions so dilute as to be unaffected by tannic acid.

Tannic acid is a valuable and delicate test of the presence of gelatin. When added to a solution containing only one-five-thousandth part of gelatin, nebulosity is immediately apparent. When more concentrated gelatinous menstrua are treated with tincture or infusion of galls, a dense, white, caseous subsidence occurs, which, on desiccation, becomes brownish-yellow, agglutinates, and forms a hard, brittle mass, easily reduced to powder.

From the investigations of MULDER, it appears that several definite and permanent combinations of gelatin with tannic acid are capable of being formed. On commingling the pure solutions of these bodies, a neutral combination, containing one equivalent of gelatin, one of tannic acid, and two of water, is formed. According to DAVY, the compound of gelatin with oak-tannin consists of—

	Centesimally
Gelatin,	54
Tannic acid,	46
	100

M. SCHIÉBEL, who obtained nearly the same results, says that one hundred parts of gelatin precipitated with a large excess of a solution of extract of oak-bark in nine parts of water, combined with 118·5 parts of tannic acid. When, on the contrary, he mixed a very dilute solution of extract of oak-bark with the solution of gelatin, without precipitating the whole of the latter, the deposit, which occupied a considerable time in subsiding, contained 59·25 per cent. of tannic acid. The gelatin was combined, in each of these cases, with different proportions of tannin, which are to each other as 1·0, 1·5, and 2·0.

Gelatin, says DUMAS, unites with various quantities of tannins derived from other sources, but never to a less extent than sixty per cent. when the precipitated menstruum contains tannin in excess.

It would sometimes be important, in researches relative to animal chemistry, to be able to separate tannin from gelatin, but this has not been effected. A dilute solution, either of caustic alkali or a carbonate, extracts much of the tannic acid, and leaves a gelatiniform, mucilaginous, swollen mass, which, with the aid of heat, dissolves in alkali like gelatin: but it is found in this case, that the solvent employed for removing the tannic acid has also taken up a certain quantity of gelatin, and if the mass in question be digested with water, a little of the gelatin dissolves out, while the remainder is converted into that combination of gelatin and tannin which has been already mentioned as so slow in depositing.

Composition.—Ultimate analyses of gelatin have been made by numerous chemists, but with different and ill-agreeing results, the foremost among them being those of Mulder, Scherer, and Goudœver: the formulæ proposed to represent its composition are, consequently, equally diverse. That, however, adopted by Löwig appears to approach nearer to the atomic combinations which have been examined, and to agree better with experiment than any other, and is adopted in the following tabulation :—

		Centesimally represented.				
	At. weight.	Theory.	Mulder.	Scherer.	Scherer.	Goudœver.
13 Eqs. Carbon,...	78	50·00	50·04	50·4	50·78	50·00
10 Eqs. Hydrogen,	10	6·41	6·47	6·9	7·15	6·72
5 Eqs. Oxygen,..	40	25·64	25·13	23·8	23·75	
2 Eqs. Nitrogen,..	28	17·95	18·36	18·9	18·32	
1 Eq. Gelatin,...	156	100·00	100·00	100·0	100·00	

Sugar of gelatin, to which allusion has already been made, was discovered by M. Braconnot. This chemist triturated one part of pulverized gelatin with double its weight of concentrated sulphuric acid, and set the mixture aside for twenty-four hours. At the end of this time the color of the liquid was not deepened. He then added eight parts of water, and subjected the menstruum to ebullition for another twenty-four hours, keeping up the quantity of water. On diluting the fluid, saturating with carbonate of lime, filtering and evaporating, a sirup was produced, which, when allowed to remain quiescent for a month, deposited granular crystals strongly adherent to the bottom of the vessel. These were edulcorated with weak alcohol, and purified by repeated crystallization.

Sugar of gelatin possesses a marked saccharine taste, very nearly allied to that of grape sugar. It is soluble in water, but not in alcohol. An aqueous solution, if kept in admixture with yeast, exhibits no sign of fermentation. According to Boussingault, the aqueous solution of gelatin sugar gives no precipitates with sulphate of copper, acetate of lead, or the nitrates of mercury and silver.

Nitric acid decomposes sugar of gelatin, giving rise to a peculiar compound, which Braconnot designated *nitrosaccharic acid*, but which it would be useless to describe here.

The composition of sugar of gelatin is as under :—

		Centesimally.	
	At. weight.	Theory.	Mulder.
8 Eqs. Carbon, ...	48	34·04	34·06
9 Eqs. Hydrogen........	9	6·38	6·49
7 Eqs. Oxygen, ...	56	39·72	39·61
2 Eqs. Nitrogen, ...	28	19·86	19·84
1 Eq. Crystallized gelatin sugar,	141	100·00	100·00

Leucin, previously mentioned as being one of the products of the decomposition of gelatin by sulphuric acid, has been shown by Mulder to be formed also during the putrefaction of casein.

Leucin has a pearly lustre. It is friable, tasteless, inodorous, and greasy to the touch, and sublimes before fusion at about 340°. It is soluble in about twenty-eight parts of water at 65°, and in six hundred and fifty-eight parts of alcohol, of specific gravity 0·828, at the same temperature. A saturated alcoholic solution becomes turbid on cooling. It is insoluble in ether, and is anhydrous, and neither acid nor alkaline.

Further, leucin, as Brande states, is soluble without decomposition in concentrated sulphuric and hydrochloric acids. Chlorine decomposes it, forming hydrochloric acid and other products, among which is a brown resinoid substance, and a red volatile fluid. It absorbs hydrochloric acid gas, forming with it a monoatomic combination. Its composition, as determined by Mulder, is as follows :—

		Centesimally.	
	At. weight.	Theory.	Mulder.
12 Eqs. Carbon, ...	72	55·39	55·53
12 Eqs. Hydrogen, ...	12	9·23	9·22
4 Eqs. Oxygen, ...	32	24·62	24·74
1 Eq. Nitrogen, ...	14	10·76	10·51
1 Eq. Leucin, ...	130	100·00	100·00

Uses.—Gelatin is employed for making jellies and blanc-manges. Considered medicinally, it is emollient and demulcent, and for this end is dissolved in water or milk, and rendered palatable by the addition of acid and sugar. Latterly, it has come into considerable use in pharmacy for the formation of capsules intended to conceal the nauseous odor and taste of medicinal preparations enclosed in them. It has likewise been used for coating pills, and certainly offers advantages not to be derived from the now almost obsolete practice of covering them with gold leaf. In the laboratory it is employed as a test for tannic acid.

Patents.—Numerous patents have been taken out for the manufacture of gelatin. Several of these are of importance, and will be briefly noticed.

In 1839, a patent was granted to George Nelson for improvements in the preparation of gelatin. The products of the process are of two kinds, which the patentee denominates as gelatin of the first and second quality. The best sort is opaque, and is by preference made from cuttings of the hides of beasts or of the skins of calves. The inferior variety is procured from *glue-pieces*, freed from hair, wool, and fleshy and fatty matters. The *modus operandi* is essentially the same in both cases, and is as follows :—The cuttings being well washed are macerated in caustic alkali at a temperature of 60°, until they are partially softened. Ten days is the period named as required to effect this. They are then placed in close vessels, and permitted to remain until a thorough softening—ascertained by passing a fork through them—is effected. They are now washed in a revolving cylinder, through which a current of water passes; exposed in a well-closed chamber to the action of sulphurous acid; submitted to pressure to remove the adhering water; and subjected to the action of steam at about 150°, till they are, as far as possible, dissolved. The menstruum is then strained, and set aside at a temperature of 100° to 120°, for the impurities which may have remained to subside; then poured upon slabs of slate or marble to the depth of about half an inch, and allowed to remain there till it has sufficiently solidified, when it is cut, and washed to remove all traces of acid. It is subsequently redissolved by means of a steam-bath at the temperature of 85°, and finally re-solidified, and exsiccated by exposure to dry air upon nets.

C. R. Roper, for whom a patent was sealed in April, 1845, prepares gelatin from bones or ivory, broken into small pieces in a digester. To each hundredweight of material is added six gallons of water, and the vessel being closed, steam is admitted at a pressure gradually raised to thirty-two pounds per square inch for three and a half hours, when the charge is withdrawn. If the bones were in a pulverulent state, it would be requisite that the gelatin should be pressed out from the residuum; but if they were merely broken into fragments, this would not be necessary. The product is now run into shallow tins or pans to solidify, and finally placed on nets to dry in the usual manner.

The specification also includes the flavoring of the gelatin with essences of lemon or almonds, for the preparation of jellies or blanc-manges.

In 1846, Arney took out a patent for the preparation of gelatin in powder, and free from water, so that it is not so liable to become mouldy, while it is reduced to such a state that it readily dissolves in water upon the application of heat. Ordinary gelatin is subjected in a stove-room to a temperature which ranges from 150° to 212°, and when the moisture is entirely dissipated, it is broken to pieces, and ground, in a mill of any ordinary kind, to a fine powder. The patentee claims, secondly, the application of gelatin in a powdered state, by means of a particular method of sweetening and flavoring, from which jellies may be prepared by dissolving it in water, and blanc-manges by infusing it in milk. He also applies his powdered gelatin, when mixed with farina or starch, or starch vegetal flour, and flavored with essence of meats, culinary herbs and spices, in the way set forth in the specification, for the purpose of thickening, enriching, and flavoring soups, gravies, *et cetera.*

In 1844, Messrs. J. and G. Cox of Edinburgh patented a process, by which they obtain a perfectly pure substance, possessing a gelatinising force superior to that of isinglass.

Shoulders and cheeks of ox hides, which are preferred by the patentees, are thoroughly cleansed in water, after which they are cut into pieces by a machine similar to that used for cutting straw, and then subjected to the action of a paper-maker's pulp-mill. By this process, the gelatinous fibre is well washed and cleansed, as a stream of water flows through the mill during the whole operation, carrying off all the impurities. The material is next pressed between rollers, mixed with fresh water sufficient to effect its solution, and heated to a temperature varying from 150° to 212°. By these means a superior gelatin is speedily produced, and it is said that the gelatinising power is not weakened by a lengthened exposure to heat.

When a very pure product is desired, the grain and flesh are removed as completely as possible from the hide pieces, the albuminous matters being thus separated. After that portion of the process already noticed has been gone through, the liquid gelatin is placed in a steam-bath, and when heated to a temperature not exceeding 160° or 170°, fresh ox blood is added, in the proportion of one gallon to seven hundred of the gelatin. As the temperature increases, the albumen of the blood becomes coagulated, partly rising as a scum to the surface of the menstruum, the other portion descending to the bottom. When the magma has all ascended, the heat is lowered, and it is removed, and the purer liquor allowed to settle for about an hour, when it is run into coolers, where it congeals, and is then cut out into any convenient way and dried, *in vacuo*, by a process similar to that for the evaporation of saccharine menstrua.

By another mode of concentration, the gelatinous solution is run upon a steam-heated surface—say pipes of half an inch diameter, placed within one-eighth of an inch apart—to the depth of about an inch. The exsiccation is then completed in the open air.

A patent was granted, in 1847, to G. P. Swinborne, for improvements in the manufacture of gelatin by the following process:—Hides or skins, or those parts of them known as glue-pieces, are cut into shavings, or thin slices or films, by any suitable instrument; these are then soaked in water, which is changed two or three times each day, until no smell or taste can be detected either in the water or in the shavings, which are then removed, subjected to heat with water sufficient to cover them when pressed down in any suitable vessel. The gelatin, thus dissolved, is strained, subjected to slight pressure, and run in thin films upon a smooth surface of slate or other material to *set*, and then placed on nets to dry in the ordinary way, and finally cut into shreds.

A fish gelatin is also prepared by the same method from cod sounds, which forms a good and cheap substitute for isinglass for clarifying liquids.

ISINGLASS.—*Colle de poisson*, French; *Fischleim*. German; *Ichthyocolla*, Latin.—The repeated mention by Dioscorides and Pliny of *ichthyocolla* has already been noticed.

Isinglass is obtained from the air-bag, or sound, as it is sometimes termed, of various fishes, many of which are still unknown. The finest kinds are produced by species of the *Acipenser*, and some other genera, as the *Morrhua*, *Silurus*, *and Gadus*.

The method of preparing the air-bags for sale, differs considerably, according to the country in which it is conducted. The commercial *pipe*, *purse*, and *lump* isinglass consist of the bag desiccated, but unopened. The *leaf* and *honeycomb* kinds are examples of the bladder cut open and dried unfolded; in the *staple* and *book* varieties, it is folded, while in the *ribbon* isinglass, it is rolled out. It is *picked* or *cut* before importation into Great Britain.

Description.—For a delineation of the various kinds of isinglass, the Editor holds himself indebted to Dr. Pereira. The very able dissertation of that pharmacologist on the various fishes from which isinglass is prepared, must, however, be omitted, as out of place here.

1. Russian and Siberian Isinglass.—The isinglass produced in the Russian empire is principally

obtained from the sturgeons. These cartilaginous fishes constitute the genus *Acipenser*. But this is not the only genus from which isinglass is obtained in Russia, for it is also procured from the *Silurus glanis*, which Dr. ROYLE suggests may be the source of the Samovey isinglass of commerce. BRANDE thus describes the preparation of Russian isinglass:—The swimming bladder is cut open, washed, and then exposed to the air with the inner silvery membrane turned upwards. The latter is then stripped off and placed in damp cloths, or left in the outer covering, and prepared or kneaded. It is then taken out of the cloths, and either merely dried—*leaf* isinglass—and twisted in a serpentine manner, between three pegs, into the shape of a horse shoe, heart, or lyre—*long* and *short staple*—or folded in the manner bookbinders fold printed sheets of paper—*book* isinglass.

Dr. PEREIRA observes in a foot-note to the above account of BRANDE, that though it agrees with the statements given by PALLAS, GMELIN, GEORGI, and TOOKE, there must be some inaccuracy in it. The immersed membrane of the swimming bladder is insoluble, though, according to BRANDE'S view, the innermost is the gelatinous membrane. According to T. W. C. MARTIN, the swimming bladders are first placed in hot water, carefully deprived of adhering blood, cut open longitudinally, and exposed to the air, with the inner delicate silvery membrane upwards. When dried, *this fine membrane is removed* by beating and rubbing, and the swimming bladder is then made into different forms.

Several kinds of leaf isinglass, says BRANDE, are imported from Russia. The finest kind is that from Astrakhan, one variety of which is said to be obtained from the Beluga—*Acipenser huso*. These are imported from St. Petersburg. The Samovey leaf is an inferior kind brought from Taganrog. Sisane leaf is the produce of a small fish, each piece measuring only about two and a half inches each way, and weighing about a drachm; it looks like pieces of dried bladder, marked by two fibrous or muscular bands. Kroski isinglass is in small circular membranous discs. Long staple isinglass is of fine quality, and is the produce of the Oural. It is usually imported loose; at times it is strung on ropes, and this latter kind is preferred. Of short staple, three varieties are known: the finest is from the Oural, and is distinguished by the name of Patriarch, but it is very scarce. The Astrakhan short staple is one of the best kinds. The Samovey short staple is of inferior quality. Two sorts of book isinglass are met with; that from the Oural is excellent, but the Samovey product is little regarded. Siberian purse isinglass is of moderately good quality, and is in general demand. A small kind on strings, in a necklace form, is sometimes imported.

2. BRAZILIAN ISINGLASS.—This is imported from Para and Maranham, and, according to GUIBOURT, is sometimes denominated Cayenne isinglass. The fishes which produce it are not known, but it is obvious, from a superficial examination of the commercial specimens, that they must have been obtained from at least several species or genera. YARREL suggests the genera Pimelodus and Silurus as the sources of it. It comes over in the form of *pipe*, *lump*, and *honeycomb*.

Pipe Brazilian isinglass must have been procured from a large fish. It is prepared by drying the swimming bladder unopened, and in some cases this is found distended with air. Each air-bag or *pipe*, as it is called, is from ten to twelve inches in length, and two or two and a half inches broad, weighing about five ounces, in shape somewhat conical, tapering at one extremity, but broader at the other, where on each side is a cæcal prolongation. It is devoid of smell. Lump Brazilian isinglass consists of two swimming bladders placed side by side, considerably separated at one end, but communicating with each other at the diverse extremity. When perfect, each specimen bears some resemblance to that of a torpedo. A perfect, though not very large lump, measured eight inches in length, and at the greatest latitude, five inches. Its weight is about six and a half ounces. It consists of three portions, separated by constrictions. The largest portion is five inches broad, and three and a half inches in length, flattish in front, rounded posteriorly. It consists of two sacs, placed one on each side. The middle portion is oblong, three inches in length, and two in breadth. This is also formed of two sacs, communicating with the preceding portion. The third portion is oblong, one and a half inches long, and three-fourths of an inch wide. This consists of one sac only, into which both sacs of the middle portion open.

Honeycomb Brazilian isinglass appears to be the largest quantity of the lump variety split open. The latter is sometimes softened, and rolled out into thin ribbons, in this country. On account of its deeper color and less solubility, Brazilian isinglass is not in demand for domestic use; though, as it is sold in the cut state, it is probably largely intermixed by shopkeepers with the finer kinds of Russian isinglass, and sold as such. As it is moderately cheap and soluble, it is in extensive use for fining by brewers, who are the principal consumers of this variety. When digested with boiling water, it leaves a large proportion of undissolved white matter of a starchy consistence.

3. *New York Isinglass.*—Occasionally, ribbon isinglass is imported from New York. It is in thin strips of several feet long, and from an inch and a half to two inches in width. It is less soluble than Russian isinglass, and affords a dark-colored solution. Dr. J. V. C. SMITH states that it is obtained from the air-bladder of the common Hake—*Gadus merluccius*—which is macerated in water for a short time, and is then taken out and subjected to pressure between two iron rollers, by which it is elongated to the extent of half a yard or more. It is then carefully dried, packed, and sent to market. The common cod—*Morrhua vulgaris*—yields a poorer kind of isinglass; but the hake only is known to the extensive manufacturers as fit for their purposes.

4. *Hudson's Bay Isinglass.*—Dr. PEREIRA was unable to ascertain from what fish this isinglass is procured. It comes over in the purse form. One specimen measured twelve inches in length, and three and a half in diameter; its weight is one ounce and a half. It is of a light yellow color, translucent, and free from

taste and smell. The inner lining of the sac, which may be readily stripped off, is insoluble in water; the remaining membrane dissolves in boiling water.

5. *East India Isinglass.*—It appears that, for a long period, this has been exported from Calcutta to China, but it has only recently occupied the attention of Europeans. It is probably the produce of a species of *Polynemus.* But, according to Dr. ROYLE, the fishes which Dr. BUCHANAN named *Bola,* and several species of *Silurus,* especially *S. raita,* also yield isinglass. Most of the specimens of Indian isinglass examined by Dr. PEREIRA had an unpleasant fishy odor, which rendered them totally unfit for household use, and greatly deteriorated their value for domestic purposes. A sample of East Indian purse isinglass, examined by Dr. PEREIRA, consisted of an unopened swimming bladder, flattened and dried. Its shape is oval-oblong, its length nine inches, its breadth three and a half inches, its weight seven and a half ounces. It has a strong fishy smell, and is of a dark color.

Another kind—East India leaf isinglass—is the sac merely laid open and dried. It is eight or nine inches long, six or seven inches broad, and about three-tenths of an inch thick. A third variety—East India rolled leaf isinglass—which Dr. PEREIRA received from Dr. ROYLE, appears to have been formed by rolling out the preceding kind into thin plates. One specimen was about eighteen inches long, three and a half inches wide, and one-tenth of an inch thick. Some of the sheets are covered with a thin film of chalk.

Picked East India isinglass is in small shreds, two or three inches long, and tapering at the extremities. It is hand-picked in India by the natives.

Manilla isinglass has been imported recently as *thin cake.* It is white and clean, and is equal in quality to Brazilian or Samovey book. The fish which yields it is found in the river of Manilla, and on the coasts of the Philippines, Luconia. It is smaller than the Brazilian, but greatly resembles the lump variety of that kind, and the fish is probably an allied species.

6. *Cod Sounds.*—These, in the dried state, are brought from Scotland, and used as a substitute for foreign isinglass. They are, however, usually preserved soft by salting, and dressed for the table.

Para Isinglass.—A substance has lately been imported under the name of isinglass, which, on examination, proves to be, not the air-bag, but the dried ovary of a large fish.

It consists of bunches—somewhat resembling those of grapes—of ovoid or rounded masses, attached by peduncles to a central axis; by immersion in water, the latter is found to be a convoluted membrane, to one side only of which these ovoid masses are attached. When soaked in water, the fishy odor of this so-called isinglass is very obvious. The ovoid masses are *ova,* are highly vascular on the surface, and are filled with an animal substance of a yellow color. In general appearance, they resemble the vitillus of a shark or ray.

The *Sudis gigas,* a large osseous fish, upwards of six feet in length, is found at Para. Its flesh is eaten by the lower classes in a dried and salted state, and its swimming bladder constitutes one of the kinds of Brazilian isinglass imported into London. It is probable that the ovary of this fish constitutes the false isinglass in question. If not from this fish, it is probably obtained from some allied genus—as *Amia*—of highly organized osseous fishes.—*Pereira's Materia Medica.*

PROPERTIES AND COMPOSITION.—The properties of isinglass are nearly the same as those of gelatin.

Isinglass was first analysed by Dr. JOHN, but his results are very questionable. They are as follow:—

	Centesimally.
Gelatin,	70·0
Osmazom,	16·0
Membrane insoluble in boiling water,	2·5
Free acid, and salts of potassa and soda, with some phosphate of lime,	4·0
Water,	7·5
	100·0

It appears that the Bengal isinglass yields, on analysis, gelatin, albumen, osmazom, a trace of odorous oil, and a small amount of inorganic matter. The quantities of the first two mentioned principles contained in three several samples of isinglass were respectively:—

	Centesimally.		
	I.	II.	III.
Gelatin,	86·5	90·9	92·8
Albumen,	13·5	9·1	7·2
	100·0	100·0	100·0

USES.—The more common kinds of isinglass, especially the coarse Brazilian, are used by brewers for fining beer, and have been noticed in their application for that purpose. They are also employed for the clarification of wines, and various other liquids.

Court Plaster is formed by brushing a solution of isinglass, mingled with a little tincture of benzoin, over black sarsenet. LISTON'S isinglass plaster is similarly made with oiled silk.

Isinglass also enters into the composition of those preparations known as *marine glue, diamond cement, et cetera.* The latter is made by dissolving isinglass in dilute alcohol. These ingredients are put in a bottle loosely corked, which is then placed in a vessel containing boiling water, and simmered for about an hour. When cold, it should be an opaque, milk-white, hard jelly; it is re-dissolved by immersion in warm water, the cork of the bottle having been previously loosened. The addition of a little spirit is required, after some time, to replace that lost by evaporation.

A better article than this may be obtained by soaking fine isinglass in cold water; when it has swelled out, spirit is added, and the bottle containing these set in a pan of *cold* water, which is gradually brought to the boiling point, when the isinglass becomes one uniform pulp, free from lumps or fibres.

These preparations have a tendency to become mouldy, which may be diminished or removed by the addition of a few drops of any essential oil.

ADULTERATION OF ISINGLASS.—The quality of cut isinglass is estimated, says Dr. REDWOOD,—1. By its color; that which is cut fine by machinery being, *cæteris paribus,* the whitest and generally most esteemed. 2. By the odor emitted after breathing upon it; that being the best which is least disagreeable in this respect. 3. By the extent of its solubility in water. 4. By the consistency, transparency, and flavor of the jelly which it gives. This practical method of examination is that alone by which slight shades of variance may be discovered; yet a difference of flavor, which only a practised palate, or careful comparison with an approved specimen could detect, is often important in an article intended for the diet of the fastidious invalid, and a slight superiority in this respect will, therefore, command a much increased price.

WARINGTON and REDWOOD have shown that sheet gelatin is rolled between sheets of isinglass in the moistened state, so as to form a ribbon in which the two substances would be united.

This may be detected by means of the microscope, the separate strata being in many cases clearly discernible. The amount of inorganic matter in the product is also a clue as to whether it is or is not adulterated, since isinglass gives an ash of a *reddish color*, amounting only to a half per cent., while gelatin gives, according to REDWOOD, not less than three per cent. of *white* ash.

They may also be distinguished from one another, says Dr. REDWOOD, by means of caustic potassa. When cut isinglass is macerated in a cold solution of caustic potassa, it will speedily become transparent, and, after the lapse of a few hours, if occasionally stirred, it will be dissolved, forming a clear and colorless solution. After allowing this to stand for some time, a *very slight* flocculent precipitate will be deposited, which, in operating on twenty or thirty grains of isinglass, will be scarcely perceptible. *Cut gelatin*, by the same treatment, becomes opaque; even those specimens which were so, to a certain extent, previously, will assume increased opacity after immersion. The gelatin ultimately dissolves, as does the isinglass; but the solution is not transparent, and after some time a *copious* flocculent deposit is formed.

A sample of hand-cut isinglass, examined by WARINGTON, had a great deal of acid adhering to it, which he considered to arise either from the acid having been used for the purpose of improving an inferior isinglass, so as to render it saleable, or from its admixture with gelatin prepared by means of an acid.

GLUE.—*Colle forte*, French; *Tischlerleim*, German.—Glue is an impure desiccated gelatin, obtained from various sources. The principal substances employed are scraps of ox and other thick hides, which afford the strongest product; the debris of the tan-yards, of leather-dressers, morocco-leather manufacturers, *et cetera*. The tendons and intestines of many animals, rabbit skins deprived of their fur, scraps of parchment, old gloves, and many other apparently worse than useless matters, all contribute their quota in the manufacture of glue.

When the fresh glue-yielding substances are not to be immediately employed, it is always requisite to submit them to some antiseptic treatment till they are required for use.

This preservation often forms the base of a particular branch of industry, which has for its object to prevent the fermentation of the raw materials, and to dry them to avoid the expenses of transport. These results are obtained by simply macerating them during fifteen to twenty days in milk of lime, which is repeatedly renewed. After taking them from the lime bath, they are spread in the open air to drain and dry. This desiccation is accelerated by turning them over with a fork several times a day. When sufficiently dried, the materials are packed up and sent to the glue factory.

The calcareous liquor serves to dissolve the blood and some soft parts; it attacks the epidermis, and predisposes the tissue to be more easily converted into gelatin. Before employing these glue-yielding materials, the manufacturer is in the habit of completing these effects by again immersing them in a weak milk of lime, which frees them still further from any soluble animal impurities. When they are much swollen and easily penetrated, they are several times rinsed in water to remove the excess of calcia. They are then spread upon hurdles, being turned occasionally to carbonate the free alkaline earth, which might subsequently be injurious to the glue. It is not necessary, however, to dry the material, as when put into the boiler it dissolves faster when in a soft or tumefied state.

Formerly the glue pieces, having been cleansed as above described, were thrown loose into the caldron, which was of copper, rather shallow in proportion to its area, and flat-bottomed. Above the true bottom there was a false one of copper or iron, perforated with numerous holes, and standing upon feet three or four inches high, the animal matters being thus upheld from contact with the fire.

Now, however, the material is placed in a wide-mouthed bag or net, made of rope, and spread open in the caldron, which contains a light framing of iron, to prevent the bag adhering to the sides or bottom. Water is then added, and gradually brought to ebullition. As the animal substances decrease in bulk, fresh additions are made, the whole being occasionally agitated or pressed down by means of poles.

The progress of the operation is readily ascertained by withdrawing a sample of the menstruum, and setting it aside for a few minutes to cool. If a clear and consistent jelly be obtained, the boiling has been carried to a sufficient extent, and the mouth of the glue-bag having been securely tied up, it is slowly raised by appropriate machinery, until it comes in contact with, or is partially coiled round, a large beam immediately above the caldron, which expels the fluid. In this state it is left to drain. The solution in the boiler will require evaporation before it is sufficiently concentrated for making glue.

The contents of the bag are subjected to ebullition for a second and a third time, and by this means afford *size*. When the resulting solutions are too dilute for either glue or size, they are employed instead of water for extracting the glue from fresh materials; the refuse in the bags, after all available matter has been extracted, is sold for manure, and every particle of animal substance is turned to account.

When sufficiently concentrated, the glue is transferred from the caldron to the *settling-back*, where such a temperature is maintained, that its fluidity is preserved. The impurities by this means subside, and should the manufacturer wish a very fine product, he can also at this time add such fining or clarifying agents as he may prefer.

The glue is run off hence into wooden *coolers* or *boxes* about six feet in length, two in depth, and one in breadth. The apartment in which this is done ought to be as cool and dry as possible, to favor the solidification of the gelatinous menstruum, and the floor should be kept scrupulously clean, so that should any glue escape it may be recovered.

Having become a firm jelly, the glue is cut out into cubic masses, each of which is deposited in a kind of wooden box, open to the back in several slits or divisions, of a size corresponding to the thickness which the cakes of glue are required to have. It is then cut into slices by passing a brass wire stretched in a frame, like that of a bow-saw along the slits. The resulting cakes of glue are deposited upon nets, which are stretched in wooden frames, and are thus removed to the sheds, where they are placed in piles, due intervals being allowed for the circulation of the air. They are turned two or three times a day.

The drying of the glue, says Dr. URE, is the most precarious part of the manufacture. The least disturbance of the weather may injure the product during the first two or three days of its exposure. Should the temperature rise considerably, the gelatin may become soft and unshapely, so much so as to run through the meshes upon the pieces below, or to get attached to the strings, and surround them so as not to be separable without plunging the net into boiling water. If frost supervene, numerous cracks may be formed in the cakes, from the congelation of their water. Such pieces must be remelted. Even a slight fog produces, upon newly-exposed glue, a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunderstorm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets. A wind too dry or too hot may cause it to exsiccate so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. Thus, as TOMLINSON remarks, the manufacture is subject to many vicissitudes, and can only be profitably and conveniently carried on in temperate and equable weather. The drying, however, is not entirely finished in the open air. When the glue is about three parts dry, it is removed into lofts, where, in the course of some time, the hardening is completed. But, as the surfaces of the cakes become mouldy and soiled, it is necessary to scour them with a brush and hot water, and set them up to drain. They are then finally desiccated in a stove-room at an elevated temperature, which, when they have once become solid, only serves to harden and improve them.

In France, a considerable quantity of glue is made from bones, which are digested in hydrochloric acid, for the purpose of removing the phosphate of lime.

The following is the *modus operandi*:—It is proper to observe that all bones do not answer for this manufacture. Only spongy bones can be used; the ribs, the back-bone, the lower jaw-bone of animals, and the horns, are those which yield the greatest amount of gelatin. The bones are broken as small as possible by means of an axe. Some hydrochloric acid of 36° Twaddell is mixed with a quantity of water, so as to reduce the mixture to 13°, which can be ascertained by means of the acidimeter. The crushed bones are put into a vessel, and the above-mentioned preparation poured over them so as to cover them completely. The vessel is covered close with a wooden lid, and the bones are thus left to macerate for thirty hours. When this period has elapsed, it must be seen if the bones are softened; for otherwise, if the acid was deficient in strength to extract from them the lime and alkali, in that case it would be requisite to change the vessel, and to give them a new maceration with a mixture of 9° Twaddell strength. When sufficiently prepared they are withdrawn, and thrown into a bath of weak lime-water, where they are left to steep eight days; they are then removed, washed with fresh water, and put to steep in a fresh portion of water daily for ten or twelve days, for the purpose of removing from the bones the acid which may have penetrated them—then dried. These glues or pastes are now good for the market, and sell at about fifty shillings the six hundred pounds.

This, says Dr. URE, is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection.

PROPERTIES.—Glue is commercially judged of by its color, and freedom from cloudy or black spots when held up before the light.

The better sorts of glue are transparent, especially the thin cakes of *Salisbury glue*, which are of a clear amber color. The chemical characteristics of glue are similar, as a matter of course, to those of pure gelatin.

According to SCHATTENMANN, fresh glue dries much more readily than glue that has been once or twice melted. He states that dry glue absorbs different quantities of water in proportion to its quality, and on this property he has proposed a method of testing it.

Fresh glue contains water of composition, or water more intimately united with the glue than that which it acquires during the melting. The combined water of dry glue disappears in the course of successive meltings and solidifications.

Glue in thin laminæ is usually of better quality than that which is in thick ones, even when made from the same material, because the former admit of a more rapid desiccation than the latter.

In applying SCHATTENMANN's test, dry glue is immersed for twenty-four hours in water at a temperature of about 60°. A jelly is thus formed, the qualities of which will fairly represent those of the glue. For example, the finest ordinary glue, or that made from white bones, absorbs, in the time specified, twelve times its weight of water, so that a plate weighing three grammes produces thirty-nine of fine elastic jelly. Glue from dark bones takes up nine times its weight of water, and a soft brown jelly is produced, devoid of elasticity and consistency, and falling to pieces when handled.

Well-dried glues are much less hydrometric than badly made ones, or those fabricated from inferior materials. The latter are liable to putrefaction.—*Tomlinson.*

APPLICATIONS.—The common, but important use of glue in carpentry, cabinet-making, *et cetera*, is well known.

There was formerly a large consumption of it for the sizeing of paper; but since this has been made without manual labor, it is almost wholly disused for this purpose.

The hatter employs it in the preparation of his felt; and the letterpress printer, in conjunction with molasses, as a flexible and cleanly covering for his inking rollers.

At the beginning of this century, glue was introduced in Germany for making moulds for casting, but it was not employed in this country till the year 1826, when Douglas Fox used it for taking casts of anatomical preparations, calcareous concretions, vegetal substances, *et cetera*. He first mixed it with treacle, for the purpose of giving to it more elasticity, but this discolored all white surfaces, and the plan was abandoned.

In 1844, Franchi formed a series of casts in plaster composition, in imitation of ivory; and, in 1846, the Society of Arts in London awarded to him a prize. The nature of the material was unknown at the time, but it was subsequently shown to be pure gelatin. The inventor has since employed it for modelling very intricate and ingenious devices.

Statistics.—A very large amount of glue, manufactured in England, is undoubtedly passed off as Russian; yet, nevertheless, a considerable quantity is imported. The returns of imports and exports, from the years 1850 to 1855, are subjoined. The reader cannot fail to notice the large decrease in the quantity imported during 1855, owing to the hostilities with Russia :—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports,......	1305	1323	1625	3359	4905	781
Exports,......	—	1	—	46	19	—

The quantity of isinglass imported, principally from the dominions of the Tzar, during the years 1850–5, was as under :—

IMPORTS.

1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt	Cwt.
2009	2387	2056	1730	1881	1567

And the exports during the same period were :—

1850.	1851.	1852.	1853.	1854.	1855.
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
78	145	117	252	72	205

The imports and exports of gelatin for the years 1850 to 1855 inclusive, were as under :—

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Imports.......	449	295	271	275	269	268
Exports,......	—	1	2	1	—	3

The quantity imported is gradually lessening, owing, most probably, to the great improvements which have been effected in the British manufacture during the last few years.

GLASS.—*Verre*, French; *Glas*, German; *Vitrum*, Latin.—The discovery of glass is, without contradiction, one of the most important services which accident or chemistry has rendered to civilization. Without speaking of the econominal uses of this compound, and considering it only with reference to its applications in the study of natural phenomena, it is impossible to doubt the singular influence it has exerted on the progress of science. It is chiefly by its aid that astronomy has attained a perfection so wonderful; by it also naturalists have been enabled to study under the microscope a host of phenomena which heretofore escaped notice. But perhaps of still greater importance is the use which is made of it by chemists in their experiments. It requires no profound chemical knowledge to recognize the fact, that to glass is chiefly owing the present advanced state of the sciences, so fruitful in marvellous applications. Every one, says Liebig, is familiar with most of the properties of this curious substance; its transparency, hardness, destitution of color, and stability under ordinary circumstances : to these obvious qualities one may add those which especially adapt it to the service of the chemist, namely, that it is unaffected by most acids or other fluids. At certain temperatures it becomes more ductile and plastic than ware, and may be made to assume in the flame of a common lamp the form of every vessel needed in the laboratory, and of every apparatus required by experimenters.

The use of glass in our windows, remarks Tomlinson, instead of the louvre boards of old, has introduced a degree of comfort into the meanest dwelling which previously did not appertain to the costliest palace. By means of this contrivance the light is filtered from the wind, the rain, and the cold; the one can be enjoyed without being inconvenienced by the other; and one can, in conjunction with the improved methods of warming, create an in-door climate, adapted to the desires and feelings of the dwellers. The employment of glass in many domestic articles of furniture contributes to cleanliness and health, for the slightest soil on glasses or decanters is revealed by this most transparent material, and the purity of the water and other liquids contained in them is physically tested by the same means. Even the mirror, adorning the rooms, reminds one of the necessary attention to personal appearance, which self-respect, as well as respect for society, demands.—*Tomlinson*.

The great Dr. Johnson has appositely remarked, that it might contribute to dispose one to a kinder regard for the labors of his fellow, if he were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he first saw the sand or ashes, by casual intenseness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniencies of life, as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once in a high degree solid and transparent, which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time, with the unbounded extent of material creation, and at another with the endless subordination of animal life; and what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in *glass* employed, though without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself.

It is not a little remarkable that glass, which is applied so extensively and to so many purposes, and the varying properties of which exercise so marked an influence in its different applications, has, notwithstanding, never been the subject of a series of decisive experiments, calculated to establish the theory of its fabrication. Not that this theory has not been nearly, if not wholly elucidated; but that it is scarcely to be looked for in the works published on glass. The greater part of these were written at a period when the part which silicic acid performed was not defined or understood; and among the recent works on the subject, Knapp's is the only one which discusses it in a thoroughly scientific manner.

Definition.—It is stated in the Encyclopedia Britannica, that the general term *glass* is employed by chemists to denote all mineral substances which, on the application of heat, pass through a molten state into hard and brittle masses, and which exhibit when broken, though not always transparent, a lustrous fracture. The glass of commerce, however, to which the present article will be restricted, or the transparent and artificial substance which is usually distinguished by this name, is produced by the igneous fusion of silicious earth with certain alkaline earths or salts, or with metallic oxides.

The etymology of the word has been much disputed. It is derived by some from the Latin *glacies*, ice, its resemblance to which is thought to have suggested the title, and *glacies* may be a contraction for *gelacies* from *gelu*, frost. Others have remarked, that the common Latin designation of this substance is *vitrum;* and as the Romans applied this term, in common with the word *glastum*, to the plant which is now called woad, they have deduced it from the latter of these, either because the ashes of this plant were used in the manufacture of glass, or because it exhibited something of the bluish tinge which is procured from woad. *Glassum*, the name given to amber by the ancient Gauls and Britons, has also been assigned as the origin of the word. But none of these etymons appears very satisfactory. The most plausible theory is that which derives the term from the Saxon verb *glis-nian*, or the German *gleissen*, which are probably contractions of the Anglo-Saxon *gel-ixan*, to shine, to be bright. This view is in a great degree confirmed by the sense in which the term glass and its derivatives are employed by our older writers, who frequently apply it to shining or glittering substances, without reference to color or transparency.—*Encyclopedia Britannica.*

Historical Notice.—In the most remote ages the art of blowing glass into bottles, making it into vases, tinging it to imitate precious stones, melting it in huge masses to make pillars, rolling and polishing it into mirrors, and staining it in parts, were all perfectly known. As stated by some authorities, Egypt, the parent of so many collateral arts, is to be looked to as its source. According to others, its discovery originated with the Israelites, who set fire to a forest, and the heat becoming so intense as to make the nitrate of soda and sand melt and flow along the mountain side, they afterwards imitated artificially what had first been effected by accident. If Pliny is to be credited—an author, whose version of the subject has so often been reproduced with all the gravity of history—the discovery of glass was made by some Phœnician soda merchants, who, having landed on the banks of the river Belus, served themselves with blocks of soda to support the vessel in which they prepared their food, and these masses melting with the heat, transformed into glass the sand on which they rested. When one knows the temperature necessary for the making of glass, and has seen the interior of a glass furnace in operation, this story will be rejected as fabulous. Chance had doubtless its share in the invention of glass; but there might have been found among the arts known to the ancients, phenomena better fitted to awaken the attention of an observant spirit. The pottery manufacture and the extraction of metals require the employment of violent and sustained fire, which is sufficient to give rise to fusible silicates, more or less analogous to glass. That an intelligent potter might have attempted to reproduce at pleasure the vitreous tears which formed accidentally upon his products; that by dint of repeated trials he might have been led to remark the influence of ashes on the clay, and that thus he might have succeeded in producing glass, is easily conceived. However this may be, the anecdote related by Pliny ought to be ranked with those idle tales or mere conjectures by which the ancient commentators sometimes attempted to fill the gap created by the silence of history, and which were afterwards transformed into articles of faith by some mistake of a copyist, or by some blunder of a new commentator. It is a point, however, on which there can be no doubt, that glass was known to the Phœnicians, who for a long time retained the monopoly of it, favored by the union of natron, sand, and fuel, in a country situated on the shores of the sea.

There are several references to glass in the Bible. Ballantyne remarks that the Hebrews must have become acquainted with glass while in Egypt, and in consequence of their proximity to the Phœnicians; and it is now generally believed that these two nations had the merit of originating and establishing its manufacture. It is a remarkable circumstance that glass lenses have been found during the recent researches in the ruins of Nineveh. The Athenian ambassadors, in order to give an idea of the magnificence displayed at the court of the great king of Persia, said that they drank in cups of glass and gold. Some writers affirm that the Egyptians, in some instances, sealed up their dead in a coating of glass; and glass houses are said to have been not uncommon in that wonderful country. Some authors ascribe, with very plausible reason, the discovery of glass-making to the priests of Vulcan at Thebes and Memphis, the greatest chemists in the ancient world. The Egyptians are also known to have made enamels of divers hues which they applied on pottery, magnificent specimens of which are still extant, and are called Egyptian porcelain. These are chiefly covered with a beautiful blue or green tinge, and groups of flowers or other designs are traced in black. Glass beads and other ornaments made of that substance, skilfully manufactured and beautifully tinged, have been found adorning mummies, which are known to be upwards of three thousand years old. It is certain that Tyre, Sidon, and Alexandria were long celebrated for their glass, and furnished the greater proportion of that used at Rome. Under the Roman empire the Egyptians still preserved their superiority in the art of glass-making, and it is said that Aurelian caused them to pay their tribute in that manufacture. Adrian mentions that he had received drinking-glasses of various shades from a priest of a famous temple in Egypt, and gives instructions that they are not to be used but on the greatest occasions, and on the most solemn feast days. To these places the art was exclusively confined for some centuries, and glass was used as an article of luxury, being chiefly in the form of urns or drinking cups of the most elaborate workmanship, and exquisitely embellished with raised, chased, or ornamented figures. The Barberini or Portland vase, composed of a deep azure glass, with figures of a delicate white opaque substance raised in relief, is a splendid specimen, and was found in the tomb of Alexander Severus.

Sir J. G. Wilkinson adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, three thousand five hundred years ago. At Beni Hassan and at Thebes are paintings representing, in a very rude form, glass-blowers at work; and from the hieroglyphics accompanying them, it is found that they were executed in the reign of a monarch who occupied the throne at about that period. It is certain, moreover, that at that time images of glazed pottery were common, the vitrified material of which is of the same quality as glass; and, therefore, the mode of fusing, and the proper proportions of the ingredients for making glass, must have been already well known. Lastly, Sir J. G. Wilkinson adduces the instance of a glass bead about three-quarters of an inch in diameter, which Captain Henry found at Thebes, and which contains in hieroglyphic characters the name of a monarch who lived fifteen hundred years before Christ. The knowledge of the manufacture probably travelled from Egypt to Greece, thence to Rome and modern Europe; and successive improvements have not only brought the art to a high degree of excellence, but have led to its subdivision into several kinds, such as flint-glass, plate-glass, window-glass, and green or bottle-glass making. —*Dodd.*

The art of glass-making seems to have been introduced into Italy by the Romans after their conquests in Asia, in the time of Cicero, and the first glass-works there were said to have been near the Flaminian Circus. It is highly probable that the workmen were imported from Egypt. The use of glass seems to have rapidly extended, and to have become very common. One of the emperors in the third century of the Christian era says, that he was disgusted with an article so mean and vulgar as glass, and that he would only drink from vessels of gold. By this time the manufacture of glass was so considerable that an impost was laid on it, and it was extensively employed in the decorations of buildings. In glass mosaics particularly were combined the most brilliant colors.

From the circumstance of colored glass beads and amulets having been found among Druidical remains in this country, says Ballantyne, it has been argued by Pennant and others, that the art of making glass was known in Britain before its invasion by the Romans. It can hardly be believed, however, that a people who had made very trifling advances in civilization, and who, it is known, were entirely unacquainted with any other art, should be found not only conversant with the use of glass, a complicated and highly ingenious process, but should excel in it; for the beads and amulets spoken of are of exquisite workmanship, and beautifully colored in imitation of the rarest and most precious stones. There seems little doubt, therefore, that the ancient Britons procured these in their traffic with the Syrians, who visited this island, as the modern Britons and other civilized nations visit the South Sea islands, to drive a trade with their savage inhabitants in toys and trinkets, giving these in exchange for skins or other natural productions. By whatever means, however, these ornaments came into Britain, it is certain that they were in extensive use, though principally for superstitious purposes, long prior to the Roman invasion, as they are found in barrows or tumuli of a much older date. One at Stonehenge, in particular, on being opened, was found to be filled with them.

Glain Neidyr, or druidical glass rings, generally about half as wide as our finger rings, but much thicker, have frequently been found. The vulgar superstition regarding these was, that they were produced by snakes joining their heads together and hissing, when a kind of bubble like a ring was formed round the head of one of them, which the others, continuing to hiss, blew upon till it came off at the tail, when it immediately hardened into a glass ring. Success was thought to attend any one who was fortunate enough to find one of those snake stones. They were evidently beads of glass employed by the Druids, under the name of charms, to deceive the vulgar. They are usually of a green hue, but some of them are blue, and others variegated with wavy streaks of blue, red, and white.

Glass utensils have been found in Herculaneum, which city was destroyed by an eruption of Mount Vesuvius in the reign of Titus. A plate of glass also found there has occasioned much speculation as to its uses. Similar plates, to which Pliny gives the name of *vitreæ cameræ*, seem to have been employed in a manner not now very well understood, as panelling for their rooms. It is certain that two panes of glass were found in a window in Herculaneum.

In the reign of Tiberius, a company of glass manufacturers established themselves in Rome, and they had a street assigned them near the Porta Capena. The articles of their manufacture were few in number, and of inferior quality; neither did they make rapid improvements in their art, notwithstanding the large prices which were then given for glass of foreign manufacture in the imperial city. In the year 220, they had increased so much in importance, and the product was so considerable, that an impost was laid on it by

Alexander Severus. Dion Cassius and Petronius Arbiter concur in their account of the discovery of malleable or ductile glass by a celebrated Roman architect, whose success in the restoration to its position of a portico which leaned to one side, had roused the envy and jealousy of Tiberius, and occasioned his banishment from Rome. Thinking that his discovery would disarm the Emperor's wrath, the artist appeared before him bearing a glass vessel, which he dashed upon the ground. Notwithstanding the violence of the blow, it was merely dimpled, as if it had been brass. Taking a hammer from his breast, he then beat it out into its original shape; but instead of giving him the reward which he had expected, the Emperor ordered the unfortunate artisan to be beheaded; remarking, that if his discovery were known, gold would soon be held of as little value as common clay. This is probably another version of the story told by Pliny, of an artificer who made the same discovery, and whose workshop was demolished by those who had an interest in preventing the introduction of an article which would lower the value of gold, silver, and brass. Although it might not be justifiable to give unqualified discredit to these tales, yet the knowledge at present possessed would restrict the possibility of such a discovery within the narrowest limits. The union of the properties of malleability and vitrification seems to be incompatible. Some metallic substances, by the application of intense heat, are reduced to the state of glass, but at the same time lose their malleability; which fact would seem to imply that it is impossible to communicate the latter property to glass. The extraordinary stories above-mentioned have, however, been rationally enough explained by modern chemists. It has been observed by Kunckel, that a composition having a glassy appearance, and sufficiently pliant to be wrought by the hammer, may be formed; and by Neumann, that, in the fusion of chloride of silver, a kind of glass results, which may be shaped or beaten into different figures, and may be pronounced in some degree ductile. Blancourt mentions an artist who presented a bust of ductile glass to the Cardinal Richelieu; but he does not seem to have been more fortunate than his predecessors; for he was doomed to imprisonment for life, for *the politic reason*, as Blancourt with much simplicity observes, which led the Cardinal to fear lest the established interests of French glass manufacturers might be injured by the discovery. From expressions used by Blancourt in other parts of his work, it is thought that by malleable glass, such as was produced by this artist, he understood some composition similar to those which Kunckel and Neumann discovered, and was not very exact in limiting the term to that vitreous substance which is now generally understood when glass is mentioned.

The precise period at which the making of window-glass was introduced, is not now certainly known. Roman windows were filled with a semi-transparent substance called *lapis specularis*, a fossil of the class of talcs, which readily splits into thin smooth laminæ, or plates. This substance is found in masses of ten or twelve inches in breadth, and three in thickness; and, when sliced, very much resembles horn, instead of which it is to this day often employed by lantern-makers. The Romans were chiefly supplied with this article from the island of Cyprus, where it abounds. So good a substitute for glass is it said to have been, that, besides being employed for the admission of light, it was also used in the construction of hothouses, for raising and protecting delicate plants; so that, by using it, the Emperor Tiberius had cucumbers at his table throughout the whole year.

There is no positive mention of the use of glass for windows before the time of Lactantius, at the close of the third century. But the passage in that writer which records the fact, also shows that the *lapis specularis* still retained its place. Glass windows are distinctly mentioned by St. Jerome, as being in use in his time. A century later, the windows of the church of St. Sophia at Constantinople are represented, by Paulus Silentiarius, as being filled with glass. After this period, frequent mention is made of them. Joannes Philippinus states that glass was fastened into the windows with plaster.

Bede asserts that glass windows were first introduced into England in the year 674, by the Abbot Benedict, who brought over artificers skilled in the art of making window-glass, to glaze the church and monastery of Wearmouth. Other authorities attribute the introduction of this luxury to Bishop Wilfred, junior, who died in 711. It would thus appear, that glass windows were first seen in England either about the seventh or the beginning of the eighth century. The use of window-glass, however, was then, and for many centuries afterwards, confined entirely to buildings appropriated to religious purposes; but, in the fourteenth century, it was so much in demand, though still confined to sacred edifices and ornamental purposes, that glazing had become a regular trade. This appears from a contract entered into by the authorities of York Cathedral in 1338, with a glazier, to glaze the west windows of that structure; a piece of work which he undertook to perform at the rate of sixpence per foot for white glass, and one shilling per foot for colored. Glass windows, however, did not become common in England till the close of the twelfth century. Until this period they were rarely to be found in private houses, and were deemed a great luxury, and a token of great magnificence. The windows of the houses were, till then, filled with oiled paper or wooden lattices. In cathedrals, these, and sheets of linen, supplied the place of glass till the eighth century; in meaner edifices, lattices continued in use till the eighteenth.

The glass of the Venetians was superior to any made elsewhere, and for many years commanded the market of nearly all Europe. Their most extensive glass-works were established at Murano, a small village in the vicinity of Venice; but the produce was always recognized as Venetian glass. Baron von Lowhen states that, so useful were the glass-makers at one period in Venice, and so great the revenue accruing to the republic from their manufacture, that, to encourage the men engaged in it to remain in Murano, the senate made them all burgesses of Venice;

and allowed the nobility to marry their daughters; whereas, if a nobleman married the daughter of any other tradesman, the issue were not reputed noble.

The skill of the Venetians in glass-making was especially remarkable in the excellence of their mirrors. BECKMANN, who has minutely investigated the subject, is of opinion that the manufacture of glass mirrors certainly was attempted, but not with complete success, in Sidon, at a very early period; but that they fell into disuse, and were almost forgotten until the thirteenth century. Previously to this period, plates of polished metal were used at the toilette; and in the rudeness of the first ideas which suggested the substitution of glass, the plates were made of a deep black color to imitate them. Black foil even was laid behind them to increase their opacity. The metal mirrors, however, remained in use long after the introduction of their fragile rivals; but at length they wholly disappeared—a result effected chiefly by the skill of the Venetians, who improved their manufacture to such a degree, that they speedily acquired a celebrity which secured an immense sale for them throughout all Europe.

From Italy the art of glass-making found its way into France, where an attempt was made to rival the Venetians in the manufacture of mirrors. The first essay was unsuccessful; but another, made under the patronage of the celebrated COLBERT, in which French workmen who had acquired a knowledge of the art at Murano were employed, had better fortune. But a few years afterwards, this establishment, which was situated in the village of Tourlaville, near Cherbourg, in Lower Normandy, was also threatened with ruin by a discovery or rather improvement in the art of glass-making, effected by one ABRAHAM THEVART. This improvement consisted in casting plates of much larger dimensions than it had hitherto been deemed possible to do. THEVART's first plates were cast at Paris, and astonished every artist by their magnitude. They were eighty-four inches long and fifty inches wide, whereas none previously made exceeded forty-five or fifty inches in length.

In 1695 the two companies, THEVART's and that at Tourlaville, united their interest, but were so unsuccessful, that in 1701 they were unable to pay their debts, and were, in consequence, compelled to discharge most of the workmen, and abandon several of their furnaces. Next year, however, a company was formed, under the management of ANTOINE D'AGINCOURT, who re-engaged the discharged workmen; and the works realized considerable profits to the proprietors—a circumstance which is attributed wholly to the prudent management of D'AGINCOURT.

Early in the fourteenth century, the French government made a concession in favor of glass-making, by decreeing, that not only should no derogation from nobility follow the practice of the art, but that none, save gentlemen or the sons of noblemen, should venture to engage in any of its branches, even as working artisans. This limitation was accompanied by a grant of a royal charter of incorporation, conveying important privileges, under which the occupation became eventually a source of great wealth to several families of distinction.

It has been said that the manufacturing of window-glass was first introduced into England in the year 1557. But a contract quoted by HORACE WALPOLE proves that this article was made in England upwards of a century before that period. This curious document is dated 1439, and bears to be a contract between the Countess of WARWICK and JOHN PRUDDE of Westminster, glazier, whom she employed, with other tradesmen, to erect and embellish a magnificent tomb for the Earl, her husband. JOHN PRUDDE is thereby bound to use no glass of England, but glass from beyond seas; a stipulation which, besides showing that the art of making window-glass was known and practised in England in the fifteenth century, seems also to indicate that the article made was inferior to what could be obtained from abroad. The finest sort of window-glass was first made at Crutched Friars, London, in 1557. The first flint-glass made in England was manufactured at the Savoy House, in the Strand; and the first plate-glass, for looking-glasses, coach windows, and similar purposes, was manufactured at Lambeth by Venetian workmen, brought over in 1670 by the Duke of BUCKINGHAM. From that period the English glass manufactories, aided by the liberal bounties granted them in cash upon glass sold for export, became powerful and successful rivals of the Venetian and French manufactories. The bounty on glass exported, which the government paid to the manufacturer, was not derived from any tax by impost or excise previously laid; for all such were returned to the manufacturer, together with the bounty, thereby lessening the actual cost of the article from twenty-five to fifty per cent., and enabling the English exporter to compete successfully in foreign markets. This bounty provision was annulled during the premiership of Sir ROBERT PEEL, together with all the excise duty on home consumption.

The art of glass-making was introduced into Scotland in the reign of JAMES VI. An exclusive right to manufacture it within the kingdom, for the space of thirty-one years, was granted to Lord GEORGE HAY in the year 1618. This right his lordship transferred in 1627, for a considerable sum, to THOMAS ROBINSON, merchant-tailor in London, who again disposed of it for two hundred and fifty pounds to Sir ROBERT MANSELL, vice-admiral of England. The first manufactory of glass in Scotland, an extremely rude one, was established at Wemyss, in Fife. Regular works were afterwards commenced at Prestonpans, Leith, and Dumbarton.

Crown-glass is now manufactured at Warrington, St. Helen's, Eccleston, Old Swan, and Newton, Lancashire; at Birmingham, Hunslet, near Leeds, and Bristol. It is also fabricated of excellent quality on the Tyne and Wear. Great improvements have recently been made in the manufacture of crown-glass, and it is asserted that this article, as made in England, is superior in quality to that of any other nation.

According to BALLANTYNE, the manufacture of glass was introduced into the American States in 1790, by ROBERT HEWES, a citizen of Boston, who erected a factory in the then forest of New Hampshire. The chief aim of Mr. HEWES was to supply window-glass, but he did not succeed. Another attempt was made in 1800, when a factory was built at Boston for making crown window-glass; but this was also unsuccessful, till a German named LINT, in 1803, took charge of the works, and the state of Massachusetts agreed to pay the proprietors a bounty on every table of window-glass they made, after which the manufacture was carried on successfully, the glass steadily improving in quality, and becoming famed through all the States as Boston window-glass. The same company erected new and more extensive works at Boston. The mystery attached to the art of glass-making followed it into America. The glass-blower was considered a magician, and myriads visited the newly-erected works, looking on the man who could transmute earthy and opaque matter into a transparent and brilliant substance, as an alchemist who could change base metal into gold.

Since the manufacture of flint-glass originated in the Eastern States, there have been above forty companies formed from time to time, nearly thirty of which have proved failures. There are now ten in operation, two of which are at East Cambridge, three at South Boston, one at Sandwich, three near New York city, and one at Philadelphia. Forty-eight thousand tons of coal, six thousand five hundred tons of silica, two thousand five hundred tons ash, nitrate of soda, *et cetera*, and three thousand eight hundred tons of lead, are annually consumed in the manufacture of flint-glass.

In the vicinity of Pittsburgh, in the Western States, are nine manufactories of flint-glass, and ten of window-glass, and in the river towns are fifteen window-glass factories.

There is good reason for supposing that the art of staining or painting glass is coeval with the art of making glass itself, since, as will be afterwards seen, it is difficult to make it without color. The possibility of subjecting this propensity to the will of the manufacturer must have very obviously presented itself, although it certainly requires much art and chemical knowledge to produce perfect specimens of this description of manufacture. This perfection seems, however, to have been attained at a very early period. It is certain that the art was known in Egypt three thousand years ago. The beautiful imitations of precious stones found adorning mummies which are known to have existed for that time have been already noticed; and frequent mention of specimens of Eastern workmanship of consummate beauty are met with, upon which great value was placed. Allusion has also been made to the fact, that the Emperor ADRIAN, whilst at Alexandria, was presented, by an Egyptian priest, with two glass cups, which sparkled with hues of every kind, and which had been used in the service of the temple—a present so highly prized by the Emperor, that he ordered them to be produced only on festivals and great solemnities. The works of CAYLUS and WINKELMANN furnish some striking instances of ancient skill in the formation of pictures by means of delicate glass fibres of various hues, which, after being fitted together with the utmost nicety, were conglutinated by fusion into a solid mass. The art of combining the various tints, so as to produce pictures in the manner now practised, is comparatively of recent date. The earliest specimens of this kind of work discover a factitious joining of different pieces of glass, differently tinged, and so arranged as, by a species of mosaic work, to produce the figure or figures wanted. The various pieces are held together generally by a vein of lead, run upon the back of the picture, precisely at their junction.

But modern ingenuity has superseded this clumsy expedient; and every color used in painting can now be introduced into one entire sheet. For a long period the pictured glass used in cathedrals was merely painted on the surface, the art of incorporating the tints with the glass by fusion, the method now practised, being unknown till the beginning of the fifteenth century. This great improvement is ascribed to a painter of Marseilles, who went to Rome during the pontificate of JULIUS II.; but his discovery went no further than the producing of different colors on different pieces of glass, and having them afterwards united in the old fashion. This art was, at a later period, greatly improved by ALBERT DURER and LUCAS of Leyden, the latter of whom brought it nearly to the state of perfection in which it now exists.

The first painted glass executed in England was in the time of King JOHN; previous to this, all stained or painted glass was imported from Italy. The next notice of it occurs in the reign of HENRY III. The treasurer of that monarch orders that there be painted on three glass windows in the chapel of St. JOHN, a little Virgin Mary holding the Child, and the Trinity, and Saint John the Apostle. Some time after he issues another mandate for two painted windows in the hall.

Even at this early period, however, England boasted of eminent native artists in glass painting, amongst the first of whom was JOHN THORNTON, glazier of Coventry. This person was employed, in the time of HENRY IV., by the dean and chapter of York cathedral, to paint the eastern window of that splendid edifice; and for the beautiful and masterly workmanship which he exhibited in this specimen of skill, he received four shillings per week of regular wages. He was bound to finish the work in less than three years, and to receive, over and above the weekly allowance, one hundred shillings for each year; and if the work was finished to the satisfaction of his employers, he was to receive, on its completion, a further sum of ten pounds. It must be recollected that the value of money was at that time much higher than in modern days.

From this period downwards there have been many skilful native artists, although the Reformation greatly impeded the progress of the art, by banishing what was deemed the ungodly ostentation of ornamented windows from churches; indeed, so serious was this interruption, that the art had nearly altogether disappeared in the reign of ELIZABETH. Amongst the most eminent glass painters who first appeared upon the revival of the art, were ISAAC OLIVER, born in 1616, and WILLIAM PRICE, who lived about the close of the seventeenth century. This last person was for many years the only glass painter in England. He is said to have discovered, what is to this day a desideratum in the art of glass staining, the secret of producing a rich, clear, bright, and transparent red, the most difficult to strike, and the most expensive of all the hues employed in glass painting. But PRICE having died soon after making this discovery, his secret was never divulged. This artist was succeeded by a person at Birmingham, who, in 1757, fitted up a window for Lord LYTTLETON, in the church of Hajely. To him succeeded one PECKIT of York, who attained considerable eminence in the art.

During all this time, however, and indeed until a comparatively recent date, painted glass was regarded as too costly and too magnificent an article to be otherwise employed than in decorating religious edifices, or the palaces of nobles; and even in the latter case was but sparingly used. Modern improvement has now placed this beautiful ornament within the reach of very ordinary circumstances; and when this is considered, it must excite a strong feeling of surprise to find how little so elegant a luxury is even yet in demand. The art of staining glass is now practised with very great success. The colors of modern artists, notwithstanding what is often urged to the contrary, equal in variety and richness those of the ancients; and, with the superior knowledge which is now possessed of the principles of drawing, and of bringing several colors together on a single sheet, encouragement alone is wanting to attract artists of talent and inventive genius to the pursuit of the art, and to carry it to a greater degree of excellence than it has ever reached in the hands of their predecessors.—*Encyclopedia Britannica.*

NATURE AND COMPOSITION OF GLASS.—The researches of BERZELIUS having removed all doubts concerning the acid character of silica, the general composition of glass now presents no difficulty of conception. This substance is the product of fusion at a high temperature of silica, or silicic acid, sometimes of boracic acid, with different salifiable bases, as potassa, soda, lime, magnesia, baryta, oxide of lead, oxide of tin, protoxide of iron, protoxide of manganese, alumina, and the sesquioxide of iron, and binoxide of manganese; the product solidifies after fusion in the form of a transparent mass, which is either colorless or not, according to the ingredients which it contains; it combines a great degree of hardness with the property of resisting the destructive action of air, water to a certain extent, and even that of the more powerful chemical agents.

It is well known that silica acts the part of a powerful acid at the temperature of a red heat, and is capable of expelling carbonic acid, hydrochloric acid, *et cetera*, from compounds, and combining with the bases named above, giving rise to solid combinations. Glass, in short, is a true salt—a silicate, and is an artificial production of a similar character to those compounds which occur so abundantly in nature; it differs, however, from these in one essential particular, that it possesses a distinctly non-crystalline structure; or is, as it is scientifically termed, *amorphous*. Glass, as is well observed by KNAPP, may be said to bear the same relation to a natural silicate of like composition, that melted sugar does to the ordinary crystallized substance.

Special Effect of the Different Constituents.—Although, in a purely chemical view, the potassa, soda, lime, oxide of lead, alumina, and oxide of iron, perform the same part, it is, nevertheless, very evident that, in practice, the employment of one of these bodies cannot be substituted indifferently for that of one or other of its analogues. There necessarily results in the product differences of fusibility, of ductility, of hardness, *et cetera*, which must be taken into consideration. Hence the necessity of classing glasses according to their composition and properties. This classification will be given afterwards. In the meantime, the characteristic effect of the different constituents on the nature of the glass may be briefly stated :—

The *silicates of soda and potassa* are the most fusible, and so much the more in proportion to the greater amount of the alkaline bases. One part of silica with two to three of potassa or soda, produces a glass which is fusible at a cherry-red heat, and soluble in cold water. Equal parts of alkali and silicic acid—silica—form a glass readily fusible, but imperfectly soluble. One equivalent of soda or potassa combined with six equivalents of silicic acid, and therefore represented by the formula,

$$\mathrm{Na\,O} \text{ or } \mathrm{K\,O} + 6\,\mathrm{Si\,O_3},$$

yield a compound fusible only by the heat of a very powerful forge. Potassa is more efficacious than soda in rendering the glass easy of fusion. A more brilliant lustre results from the use of soda, but at the same time a bluish-green tint is communicated to the glass. No coloring action is exerted by potassa; but the brilliancy of the glass is somewhat diminished by it.

The *silicates of lime* are much less fusible than those of the alkalies. The most fusible of the former, represented by the formula $\mathrm{Ca\,O} + \mathrm{Si\,O_3}$, requires for its fusion the violent heat of a forge. The others, represented by

$$3\,\mathrm{Ca\,O} + \mathrm{Si\,O_3}, \text{ or } 4\,\mathrm{Ca\,O} + \mathrm{Si_3\,O},$$

are only softened at the same temperature; the corresponding *silicates of magnesia* are not more fusible. Lime increases the hardness of the glass, and adds more to its lustre than the alkalies, without coloring the produce.

The *silicates of alumina* are still more refractory than the preceding. The least infusible, represented by $\mathrm{Al_2\,O_3}, 3\,\mathrm{Si\,O_3}$, is scarcely softened in the heat of a furnace. Of all the ingredients, alumina exerts the most powerful effect in increasing the difficulty of fusion.

The *silicates of the protoxides of iron and manganese* are more fusible than those of lime and magnesia, especially when they consist of one equivalent of each ingredient, thus—

$$\mathrm{Mn\,O}, \mathrm{Si\,O_3}, \text{ or } \mathrm{Fe\,O}, \mathrm{Si\,O_3}.$$

The silicate of protoxide of iron has a dark-green color, but may be decolored by bringing it to the state of a silicate of the sesquioxide; this is effected by adding a small quantity of binoxide of manganese. Care must be taken not to add it in excess, for in this case it would communicate a violet color to the glass. The binoxide, $\mathrm{Mn\,O_2}$, when added in small quantity, is converted into protoxide, $\mathrm{Mn\,O}$; but if any excess has been employed, it becomes reduced at a red heat to sesquioxide, $\mathrm{Mn_2\,O_3}$, and produces a deep amethystine-red glass.

The *silicates of the oxides of lead* are the more fusible in proportion to the greater amount of the base. With equal equivalents, the silicate of lead, $\mathrm{Pb\,O} +$

$Si\,O_3$, melts at a red heat. In fact, oxide of lead exerts a directly opposite action to alumina, being a prominent ingredient in the easily fusible varieties of glass, which are also characterized by great softness, a high brilliancy, perfect absence of color, and by the property of refracting light more powerfully than any other kind. The silicates of the oxide of zinc present analogous properties.

Baryta also exerts a similar, although less energetic action than lead.

These different silicates react on one another, and reciprocally modify each other; in composition, they become more stable, less fusible, and less subject to crystallize. Hence the advantage of the complex proportions employed in the glass and crystal manufactories.

When *boracic acid* is added, it forms boro-silicates, often more fusible, more ductile, easier to work, and producing less waste, especially in table-ware and plate-glass manufacture. M. PAYEN remarks that the experiments undertaken by MM. MAES and CLEMANDOT on crystal, with a base of oxide of zinc, yielded products remarkable for their whiteness, their transparency, their hardness, and the brilliant reflection of their cut faces.

In the words of KNAPP, it follows, as a general conclusion, from what has been stated, that those varieties of glass which possess the highest degree of lustre and power of refraction, will also be the softest—that is, the most easily scratched. They are likewise those which exhibit the highest specific gravity—from 2·8 to 3·6—and, as might be deduced from that circumstance, they—at least as far as the colorless glasses are concerned—are those which contain bases with a very high atomic weight—oxide of lead, baryta. Those bases, on the contrary, which render the glass hard and durable, appear to produce little lustre or power of refraction. The specific gravity of these varieties lies between 2·37 and 2·56. Strictly speaking, the alkalies, lime, and oxide of lead, are the only bases expressly contained in the mixture for the manufacture of glass, without reference to the different coloring and decoloring matters. Magnesia sometimes accompanies the lime, and enters, but in small quantity only, into the composition of the glass. Alumina and oxide of iron are, in like manner, only casual constituents, being contained as impurities in the other ingredients. Even in those cases where these two bases enter in large quantities into the composition of glass, they are never expressly added to the mixture; but are always derived from the impure materials. Thus, in the manufacture of ordinary bottle-glass, where color is of no moment, substances containing iron and alumina are employed. The origin of the small quantity of alumina which is found in glass that should properly be free from it, must be traced to the sides of the pots or crucibles in which the glass has been fused.—*Knapp.*

The metallic oxides which have not been mentioned, as those of gold, silver, copper, give rise to a great variety of intense colors, and are consequently used in the manufacture as pigments.

Commercial varieties of Glass.—Before proceeding to a more minute inquiry into the physical and chemical properties of glass, as these are affected by differences either in the ingredients or their properties, or in the processes followed, it will be proper to place before the reader a summary view of the characters and composition of the different varieties of glass, as preliminary to a more detailed exposition, not only of the special properties, but also of the special manufacture of each of these varieties.

There is much difficulty in dividing the glasses according to any definite principle. One of the simplest arrangements is given by TOMLINSON, as follows:—

1. Silicate of potassa and oxide of lead. Examples:—*Flint-glass*, *crystal*, and *strass.*

2. Silicate of soda and lime; or silicate of potassa, soda, and lime. Examples:—*Common window*, *English crown*, and *plate.*

3. Silicate of potassa and lime. Examples:—*Foreign crown*, *refractory Bohemian glass.*

4. Silicate of soda, lime, alumina, and oxide of iron. Example:—*Coarse green wine-bottle glass.*

The following arrangement, somewhat similar to that proposed by KNAPP, will form the basis of that adopted in the present article, beginning, as a general rule, with the coarser, and advancing by a pretty regular gradation to the finer or rarer varieties.

1. BOTTLE-GLASS, or what is more properly described by the German term *Hohlglase*, or *Hollow glass*, comprises all glass worked into the form of vessels or tubes. According to the purity of the *metal*, which is the technical term given to glass in the fused state, this variety is subdivided into different qualities, such as—*Ordinary bottle-glass*, consisting of silica, potassa or soda, lime, alumina, and oxide of iron; *glass used for medicinal bottles*, consisting of silica, soda, lime, some alumina, and a very little protoxide of iron: *white bottle-glass* for bottles or phials, tumblers, tubes—containing silica, soda or potassa, and lime. It is evident, therefore, that under the general term *Bottle-glass* or *Hohl-glass*, are included different vitreous compositions. Its distinguishing characteristic, as applied to ordinary bottle-glass, is the presence of protoxide of iron; and therefore it may be described, in general terms, as a silicate of potassa or soda, of lime, of alumina, and oxide of iron.

2. WINDOW-GLASS, including *English crown* and *cylinder* or *sheet-glass:* this is a silicate of potassa or soda, lime, and alumina.

3. PLATE-GLASS, composed of silica, soda, or potassa, lime, and a little alumina. This variety only differs from the preceding by the greater purity and freedom from color of the materials.

4. FLINT-GLASS, used for grinding, *et cetera*, composed of silica, potassa, and oxide of lead.

5. CRYSTAL, for optical purposes and table-ware, consists of silica or boracic acid, potassa, and more lead than the preceding. In short, it is a simple flint-glass, formed with very pure materials.

6. STRASS, or the substance composing the imitation of precious stones, known as paste, consists of silica, potassa, with a still larger amount of oxide of lead, and colored by various materials.

7. ENAMEL, a silicate and stannate or antimoniate of potassa or soda, and of oxide of lead. It may be other-

wise described as composed of silica, soda or potassa, and oxide of lead,—rendered opaque by oxide of tin or antimony.

8. SOLUBLE GLASS, which is a simple silicate of potassa or of soda, or a mixture of these two silicates.

The manufacture, the distinguishing properties, and the special applications of these different kinds of glass, will be described afterwards. *Strass* and *enamel* have been already treated under the latter head, and will, therefore, be only briefly alluded to in the present article. The *soluble glass*, which is used only for special purposes, such as a protective varnish for pictures, a fireproof coating for building-materials, *et cetera*, is scarcely entitled to be ranked as a true glass; but its character and applications will be stated in a future page. In the meantime, the following tables, which are given by KNAPP, with notes by RICHARDSON and RONALDS, will be found useful for reference, as showing the proportional composition of the more important glasses according to different analysts of high authority:—

BOTTLE-GLASS.

Variety of Glass.	Analysts.				
	Berthier.			Dumas.	
	1.	2.	3.	4.	5.
Silica,	60·0	60·4	59·6	53·55	45·6
Soda,	3·1	3·2	—	—	—
Potassa,	3·1	3·2	3·2	5·48	6·1
Lime,	22·3	20·7	18·0	29·22	28·1
Magnesia,	—	0·6	7·0	—	—
Baryta,	—	0·9	—	—	—
Oxide of manganese,	1·2	—	0·4	—	—
Alumina,	8·0	10·4	6·8	6·01	14·0
Oxide of iron,	4·0	3·8	4·4	5·74	6·2
Oxide of manganese,	—	—	—	—	—
Relation between the oxygen of the acid, and the total amount of oxygen contained in the bases,	5 : 2	?	7 : 3	2 : 1	4 : 3
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,	4 : 3	?	2 : 1	2 : 1	1 : 1

No. 1—Glass from Souvigny. No. 2—From St. Etienne. No. 3—From Epinac. No. 4—From Sèvres, near Paris. No. 5—From an unknown glass-house, but of French manufacture.

BOHEMIAN GLASS.—The Bohemian flint-glass is distinguished from the others by containing no lead.

Mr. ROWNEY has lately analysed the Bohemian hard glass tubing, so indispensable to chemists in the prosecution of researches in organic chemistry, and finds it to be essentially a silicate of lime and potassa, in which the oxygen in the silicic acid is to that contained in the bases as 6 to 1. Analysis yielded:—

	Centesimally represented.
Silica,	73·0
Potassa,	11·5
Soda,	3·0
Lime,	10·5
Magnesia, Alumina, Sesquioxide of iron, Oxide of manganese,	2·0
	100·0

It may, however, be remarked, that this tubing is by no means of uniform composition, as all who have been much occupied with organic analysis will have found to their cost; some tubes being much more fusible than others.

The opal is very similar to hyalite, *muller glass*, a hydrate of silica. The composition is remarkable: it is a simple silicate of potassa, which, from being imperfectly melted, remains semi-transparent, with pieces of quartz dispersed through the mass. It does not attract moisture, and is not attacked by boiling water. It differs from FUCH's soluble glass, by containing ten per cent. more silica.

The Venetian contains also traces of magnesia and phosphoric or boracic acid; the crystals appear disseminated through the mass, which is of a yellow tint, and transparent in thin sheets. The tin and iron obviously assist in the formation of the crystals of metallic copper, after which the tin becomes silicate of the protoxide, otherwise the glass would become opaque.

MEDICINAL GLASS.

Variety of Glass.	Analyst—Berthier.			
	1.	2.	3.	4.
Silica,	71·6	62·5	69·6	62·0
Soda,	—	—	3·0	16·4
Potassa,	10·6	10·5	8·0	—
Lime,	10·0	16·2	13·0	15·6
Magnesia,	—	—	0·6	2·2
Alumina,	3·0	4·5	3·6	2·4
Oxide of manganese,	0·3	1·2	—	—
Oxide of lead,	1·5	2·5	1·6	0·7
Relation between the oxygen of the acid and the total amount of oxygen in the bases,	6 : 1	7 : 2	9 : 2	5 : 1
Relation between the oxygen in the bases with one equivalent of that element, and that contained in the bases with three equivalents of oxygen,	2 : 1	7 : 3	3 : 1	9 : 1

All the varieties were of French manufacture.

DIFFERENT VARIETIES OF WHITE GLASS.

Variety of Glass.	Analysts.				
	Berthier.	Gros.	Dumas	Berthier.	Dumas.
	1.	2.	3.	4.	5.
Silica,	71·7	71·6	69·4	69·2	62·8
Soda,	12·7	11·0	11·8	15·8	22·1
Potassa,	2·5	—	—	3·0	—
Lime,	10·3	10·0	9·2	7·6	12·5
Magnesia,	—	2·3	—	2·0	—
Oxide of manganese,	0·2	0·2	—	—	—
Alumina,	0·4	2·2	9·6	1·2	2·6
Oxide of iron,	0 3	3·9	—	0·5	2·6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	6 : 1	6 : 1	4 : 1	4 : 1	5 : 1

1. Specimen of a goblet from Nenfeld in Bohemia. 2. Specimen from the same place. 3. Bohemian glass. 4. Specimen of easily fusible French glass tubing. 5. Specimen of crown-glass.

WINDOW-GLASS.

Variety of Glass.	Analysts.								
	Dumas.							Richardson	Cowper
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica,	69·65	69·25	68·55	68·65	68·5	68·0	69·0	66·37	71·4
Soda,	15·22	11·30	12·88	17·70	13·7	10·1	11·1	14·23	15·0
Lime,	13·31	17·25	16·17	9·65	7·8	14·3	12·5	11·86	12·4
Alumina,	1·82	2·20	2·40	4·00	10·0	7·6	7·4	8·16	0·6
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	4 : 1	4 : 1	4 : 1	4 : 1	7 : 2	7 : 2	7 : 2	7 : 2	9 : 2

The numbers from 1 to 6 are of French origin; numbers 7, 8, and 9 are English.

The specimen was analysed by COWPER, manufactured by Messrs. CHANCE of Birmingham. and is remarkable for containing more silica and less alumina than any of the other varieties. Mr. COWPER also found 0·3 oxide of iron, and 0·3 oxide of manganese in this sample.

PLATE-GLASS.

Variety of Glass.	Analysts.				
	Berthier.	Tassaers	Dumas.		Berthier.
	1.	2.	3.	4.	1.
Silica,	72·0	76·0	75·9	73·85	68·6
Soda,	—	—	—	5·50	6·9
Potassa,	17·0	17·0	17·5	12·05	8·1
Lime,	6·4	6·0	3·8	5·60	11·0
Magnesia,	—	—	—	—	2·1
Alumina,	2·6	—	2·8	3·50	1·2
Oxide of manganese,	—	—	—	—	0·1
Oxide of iron,	1·9	1·0	—	—	0·2
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	6 : 1	?	7 : 1	7 : 1	5 : 1

The last specimen was Venetian, the others were French glass.

CRYSTAL.

Variety of Glass.	Analysts.				
	Berthier.			Dumas	Faraday.
	1.	2.	3.	4.	5.
Silica,	59·2	56·0	51·4	56·0	51·93
Potassa,	9·0	6·6	9·4	8·9	13·67
Lime,	—	—	—	2·6	—
Alumina,	—	1·0	1·2	—	—
Oxide of lead,	28·2	34·4	37·4	32·5	33·28
Oxide of manganese,	1·0	—	—	—	—
Oxide of iron,	0·4	—	0·8	trace	—
Relation between the oxygen of the acid, and the total amount of oxygen in the bases,	8 : 1	8 : 1	6 : 1	6 : 1	6 : 1

1. From London, intended for optical instruments. 2. From Voneche in Belgium. 3. From Newcastle. 4. Of unknown origin. 5, From England.

The oxide of lead which is used in the manufacture of crystal, is not the protoxide commonly known as *massicot*, and represented by the formula $Pb\,O$, but *minium*, which is a sesquioxide, $Pb_2\,O_3$; for, as BARRUEL remarks, one may depend on the latter not being mixed with metallic lead, which almost necessarily happens with the massicot of commerce. The object of employing oxide of lead in this kind of glass is to increase the density, and, consequently, the refractive power, which gives the glass a peculiar lustre or brilliancy.

FLINT-GLASS, STRASS, AND ENAMEL.

Variety of Glass.	Analysts.			
	Faraday.	Dumas	Dumas.	Dumas
	Flint-glass from Guinand.		Strass manufactured by Donault Wieland.	Enam
Silica,	44·3	42·5	38·5	31·6
Potassa,	11·75	11·7	7·9	8·3
Lime,	—	0·5	—	—
Alumina,	—	1·8	1·0	—
Oxide of lead,	43·05	43·5	53·0	50·3
Oxide of tin,	—	—	—	9·8
Relation between the oxygen in the acid, and the total amount of oxygen in the bases,	9 : 2	4 : 1	7 : 2	7 : 3

The following analyses by PELIGOT are given by RICHARDSON and RONALDS as quite recent:—

	Bohemian glass.	Bohemian opal-glass.	Venetian aventurine.	Bohemian mirror-glass.
Silica,	76	80·9	67·7	67·7
Potassa,	15	17·6	5·5	21·0
Soda,	—	—	7·1	—
Lime,	8	·7	8·9	9·9
Alumina,	1	·8	—	1·4
Oxide of tin,	—	—	2·3	—
Oxide of lead,	—	—	1·1	—
Copper,	—	—	metallic 3·9	—
Oxide of iron,	—	traces	3·5	—
	100	100·0	100·0	100·0

Chemical Constitution of the Different Glasses.—From a careful inspection of the preceding tables, it will be seen that all the constituents of the different varieties of glass are in a state of chemical combination. It follows that the individual constituents must be united in equivalent proportions; and though these relations are sometimes difficult to trace, in consequence of different oxides replacing each other, still, the regularity of the composition is always shown by the existence of a simple relation between the collective amount of oxygen in the bases, and that contained in the silica or silicic acid. The combination in definite proportions is rendered more obvious, as KNAPP observes, when the empirical formulæ are deduced from the composition in 100 parts. Thus, by referring to the numbers of the columns in the preceding tables, the composition in 100 parts of each of the glasses specified, will be represented as follows:—

Bottle-glass, No. 5,	corresponds to	$KO + 8\ Ca\ O + ?\ Al_2\ O_3 + F_2\ O_3 + 8\ Si\ O_3$;
Window-glass, No. 2,	,,	$3\ Na\ O + 5\ Ca\ O + 12\ Si\ O_3$;
Plate-glass, No. 1,	,,	$2\ Na\ O + Ca\ O + 6\ Si\ O_3$;
White Crown-glass, No. 5,	,,	$KO + Ca\ O + 3\ Si\ O_3$;
Crystal, No. 2,	,,	$KO + 2\ PbO + 8\ Si\ O_3$;
Flint-glass, No. 2,	,,	$6\ KO + 9\ PbO\ 20\ Si\ O_3$;
Strass, No. 1,	,,	$3\ KO + 9\ PbO + 16\ Si\ O_3$; *et cetera.*

KNAPP further justly remarks, that although more probable suppositions may be formed with reference to the manner in which the silica is divided amongst the bases, and although the preceding calculations do not lead to any rational formulæ, yet the knowledge of the empirical composition for any species of glass, as represented in the examples above given, is nevertheless a very valuable guide in mixing the ingredients for its manufacture, and of great service in improving or correcting the prescribed rules.

Comparative Fusibility of the Glasses.—Under the influence of a cherry-red heat and upwards, the different kinds of glass are all capable of being first softened and then undergoing a complete fusion. At the same time, the difficult fusibility of the bi and tri silicates, or those in which the acid preponderates, and the opposite properties of those which contain a larger proportion of base, are very important facts in connection with the manufacture of glass. Silicic acid *per se*, is perfectly infusible in every furnace, but it acquires the property of fusibility in a greater or lesser degree, according to the quantity of base with which it is mixed. Glass-makers, in short, call all the bases *fluxes*, and are well aware that the work is facilitated and fuel saved by increasing the amount of flux in the mixture; but, at the same time, they know that the addition of flux cannot exceed a certain limit without detriment to the durability of the glass. When glass is attacked by reagents, under ordinary circumstances, it is always a result of the removal of base; but this is a subject for future consideration. As already stated, glasses with a lead base are the most fusible, and the more so in proportion as they contain a more considerable quantity of oxide of lead. Common glasses, on the contrary, are less so, the more lime and alumina they hold. Thus, strass, flint-glass, and crystal, are more fusible than common or window-glass, and the latter is a little more so than bottle-glass.

Imperfect Fluidity of Glass.—The possibility of casting or moulding glass, as well as its purification, depends upon the fact that at very intense heats the so-called *metal* is tolerably fluid, though still possessing a consistence which may be compared to that of weak sirup. In this state the heavier impurities are enabled to subside to the bottom, while the bubbles of gas, which too often form flaws in glass, rise by their levity to the surface. At a brisk red heat, on the contrary, the metal is only in a semi-fluid state, and on this peculiar and valuable property depends the possibility of working it into every variety of form. In this state it is an exceedingly tough, thick mass, possessing great ductility, and capable of being drawn out into the finest threads, or blown into the form of the thinnest hollow spheres. In short, it is evident that the usual methods of working glass by *blowing*, and of soldering different pieces together by simple pressure or contact, would be quite impracticable, unless the mass possessed these properties.

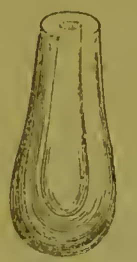
BRITTLENESS.—When glass has been heated to the softening point, and exposed to a rapid cooling, it is very brittle; when, on the contrary, it is submitted to a slow cooling, it becomes capable of resisting pretty severe shocks without breaking, and it stands equally well sudden variations of temperature. These phenomena have been compared to the tempering of steel; and although the explanations which have been given of them are not quite satisfactory, yet it will be necessary to enter into some details, on account of the practical importance of the subject. The metamorphosis has been attributed to unequal crystallization. It will be seen afterwards that the particles of glass always exhibit in the fluid state a tendency to arrange themselves in a regular manner, and form crystals. Now, when the mass is cooled suddenly, no time is allowed the particles to follow this tendency, and they are forced, as it were, against their inclination to remain in that relative position towards each other which they assumed during the working, or, in other words, to form an amorphous mass. This forced relative position of the particles is greatest where the glass has been rapidly cooled; the interior of the mass is, therefore, not so subject to it as the surface, and this latter also contracts in a greater degree. The outer layers are, consequently, in a state of tension, with reference to those in the interior. It is obvious, from these facts, that there must be a want of uniformity in the attractions of the particles of glass for each other; that a tendency to subvert the force of cohesion has been induced, which the slightest impulse from without will be sufficient to call into action. This circumstance perfectly explains the brittle nature of glass, which sometimes rises to a very extraordinary degree. For example, if one takes a little melted glass, and allows it to fall, drop by drop, into cold water, each drop will suddenly solidify, and will take a form generally spheroidal or ovoidal, terminated by a tail which ends in a rapidly tapering point, *a*, as represented in Fig. 135. The surface of this drop of glass is harder than ordinary. But by merely breaking off the point, the tension is called into play, and the whole mass flies to pieces, or rather is instantly converted into a fine powder, with a slight detonation. These little articles are known, from their great brittleness, under the name of *Rupert's drops*.

Fig. 135.

The effect is explained by DUMAS, by supposing that by the immersion in cold water the surface of the glass is suddenly solidified, the central parts being still fire-red, and consequently much dilated. When these last become solidified and cooled down, they must have retained points of adherence to the surface, and consequently occupy a larger volume than that which agrees with the temperature to which they are reduced; the central molecules are, therefore, more distended than usual, and exert a powerful contracting force on the surrounding parts. At the instant when a part of the envelope or outer portion is broken, the molecules which had been retained by it briskly contract, draw in with them all the others, and thus determine a multitude of points of rupture; as this effect is instantaneous, each fragment is shot with force, and drives the air before it; this fluid, therefore, undergoes a sudden dilatation and contraction, from which results the detonation that is heard.

The same effect is produced under another form, in what is termed the *Bologna* or *philosophical phial*—Fig. 136. This is a kind of short tube, thick, and closed at one end, which is obtained at crystal manufactories, by blowing a small portion of glass to judge of the state of the metal in the pots during the melting. These tubes are very thick, for they must be sufficiently so to allow of appreciating exactly the tint of the glass. They are exposed to a rapid cooling, because the object which they are intended to serve does not require that any care should be taken in that respect. This cooling is even accelerated by shaking in the air the rod which supports the small tube. The latter is then, in point of fact, in a state very analogous to that of the Rupert drops, and DUMAS explains their remarkable brittleness in the same manner. The interior parts have undergone a slow, and the exterior parts, on the contrary, a rapid cooling; and when these tubes are struck, even very strongly, on the outside, they do not break, while the slightest stroke on the inside is sufficient to make them fly in pieces, with a detonation similar to that which occurs in the case of the Rupert drops. A small marble, a bit of glass allowed to fall into the interior of the tube, is sufficient to make it burst asunder.

Fig. 136.



Phenomena more or less analogous to these happen with glass vessels of some thickness, which are sold for common uses. By slight variations of temperature, such as occur when they are carried from a room without a fire into a warm room, it sometimes happens that these glasses suddenly burst without any apparent cause. It is obvious, that the thicker the glasses, the more readily will effects of this kind be produced. Tubes of glass somewhat thick, and especially those which are of unequal thickness, are also very subject to split, and usually the crack is prolonged through the whole length of the tube. But glass tubes are not submitted to that particular operation, the object of which is to render glasses less liable to break by sudden changes of temperature. This operation is termed *annealing*, and consists in submitting the glass to a very slow refrigeration. The details of the process will be described in connection with the general arrangements of the glass-house and its furnaces, among which the annealing arch or oven takes an important place.

It would seem that the ordinary annealing of glass, whether it be that the operation is badly performed, or that it has not a durable effect, always leaves something to be desired. For some articles, a method of annealing is employed which is very simple, but, at the same time, expensive, if required to be applied on a large scale. It consists in placing the glass vessels in a trough or pan, taking the precaution to separate them by a little hay or straw. The vessels and the pan are filled with water, and the liquid is brought to ebullition. The whole is then left to cool slowly. The vessels thus treated are, so to speak, insured against any rapid change of temperature, comprised within the interval of 180° Fahr., or thereabouts. By using a bath of water charged with some salt, an oil-bath, or a bath of fusible alloy, this method might be extended to higher temperatures.

The efficacy of the process rests on the great difference which exists between the conducting power of air and that of liquids. There is no doubt that in the operation of annealing in the air, different points of the surface are cooled at different rates, a circumstance which can never occur when the annealing is effected under a liquid mass. It is well known in laboratories, that vessels which have accidentally undergone an annealing of this kind, are thereby rendered very fit to support, without breaking, rapid changes of temperature.

On the whole, although the brittleness of glass is not entirely obviated by the most careful annealing, yet it is so modified that the vessels, with a little care, can be used for all ordinary purposes. Sudden changes of temperature, or partial application of heat, will cause the fracture of unannealed glass quite as surely as a blow, by expanding it more at one part than another.

DEVITRIFIED, OR SEMI-CRYSTALLISED GLASS.—As excessive brittleness results from the sudden cooling of glass, so, on the other hand, when the fused metal is cooled too slowly, the amorphous state entirely disappears, the mass assumes a crystalline structure, and other changes occur which are termed *devitrification*. If the glass contain different bases, a partial separation takes place; the silica divides itself between the bases, and thus forms compounds of definite proportions which crystallize separately. In this case the intimate mixture of the materials which constitute the true glass is destroyed; the glass becomes *very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat.* The first glass of this kind was produced and described by RÉAUMUR, and was termed by him *devitrified glass.*

The devitrification of glass is a general phenomenon, which exhibits itself in all kinds of glass, but especially in glass with several earthy bases, and more difficultly in plumbiferous glasses, or glasses simply alkaline. It is almost always produced by melting the glass, and allowing it to cool very slowly, or else by heating the glass to the softening point, and submitting it to a prolonged heat and a graduated cooling. The operation succeeds better in bottle-glass than in any others: then comes common green glass, next white glass, then simple glass, with a soda base; after this, flint-glass, and, lastly, simple glass, with a potassa base.

This property exerts so great an influence in the manufacture of glass, that it is difficult not to make an immediate application of it. It explains, indeed, why, in tho making of bottles, so much care is taken to avoid the repeated reheating of the mass which is to be formed into that article. It would be thoroughly devitrified in a few seconds; the glass would become hard, difficult to fuse, and would present a multitude of solid grains disseminated in a matter still soft. One sees in the same manner why green glass, and even common white glass, and, still more so, bottle glass, can only be shaped by the lamp of the enameller when the work is performed with the necessary despatch. If he works so slowly that he is obliged to reheat several times the glass tube which he is blowing, the mass devitrifies, and all the phenomena show themselves which have just been described. In vain does he then try to blow a bulb—all the force of his lungs will not avail; the glass is no longer soft. Besides, the material then becomes rugous, semi-opaque, and almost infusible.

One can understand, on the same principles, how important it is to select with care glasses intended to be used in large and thick masses, such as those designed for the making of lenses for large optical instruments. The cooling of such masses is necessarily very slow, which induces the devitrification of the glass. It is almost impossible to succeed, therefore, except with glass having a base of lead and potassa, and glass with a base of potassa and lime. Indeed, these two kinds of glass, which constitute *flint* and *foreign crown* glass, are employed exclusively on the Continent for the making of objectives for achromatic telescopes.

The devitrification of glasses is a phenomenon of the greatest interest, and to which the attention of glass-makers cannot be too much directed. It will appear still more worthy of consideration when it is shown that, in virtue of its properties, devitrified glass is capable of replacing porcelain in almost all its uses. Thus, for the requirements of chemistry, one may make tubes, retorts, receivers, capsules, which resist the fire as well as vessels of porcelain, which are as impermeable as common glass, which resist acids very well, and which, in fine, may be obtained in a single piece, under a thousand diversified forms, which the moulding of porcelain could only furnish with difficulty. This is a business to be created, and a very important business, for it would furnish vessels of a wholesome, elegant ware, and at a comparatively low price.

To effect the devitrification of glass, RÉAUMUR selected common bottle or green glass. He filled the vessels with a mixture of roasted sulphate of lime and white sand, reduced to fine powder. He introduced them into an earthen box, which itself was filled with a similar mixture, taking care that the vessels were well isolated from each other, as well as from the sides of the box, the empty space being occupied with the plaster and sand. The box, thus prepared, fitted with a lid and luted, was carried into a pottery furnace, and left to itself during the whole duration of a firing. At the end of that time the glass was entirely devitrified.

The fracture of this glass is silky, and an attentive examination of it is sufficient to show how the phenomenon is produced. In fact, exactly in the middle of its thickness, the glass presents a brown line, and it is at this point that an infinite number of small crystalline needles meet, proceeding from the exterior and interior surface of the vessel. These needles, perfectly parallel to each other, are perpendicular to the surface of the glass, as well as to the plane passing through the line of junction, which itself follows all the variations of form in the glass. It may be added, that in glasses imperfectly devitrified the two surfaces exhibit similar needles, but too short to meet, and, consequently, separated by a greater or less breadth of common glass, which occupies the middle of the thickness of the plate or vessel. It is evident, therefore, that whatever cause determines the crystallization of the glass, acts first on the surfaces, and afterwards penetrates to the middle, till the crystals setting out from the two opposite points come to meet.

M. DARTIGUES was convinced that the gypsum and sand mixture was not indispensable, and that bottle-glass, heated only to redness during some hours, was entirely devitrified. Nevertheless, the potassa volatilizes during the devitrification, which indicates the utility of a silicious cement, which then performs the part of an absorbing body in the manner of the sulphuric acid in LESLIE's experiment for freezing water in a vacuum.

RÉAUMUR did not well understand the theory of the phenomenon of devitrification, and, subsequently, KEIR, PAJOT-DES-CHARMES, and some other observers, in examining and describing the crystallizations which sometimes occur in glass, were not more successful in perceiving the intimate connection between these two classes of facts. The researches of DARTIGUES as well as those of FLEURIAU DE BELLEVUE, ultimately placed beyond doubt the complete identity of these two phenomena.

Devitrification is therefore a crystallization of glass. Experience proves that glass, slowly cooled, almost always crystallizes when the passage from the liquid to the solid state is effected so gently as to allow the requisite molecular arrangements to take place. But it appears that, by applying this idea in an absolute manner to the devitrified glasses of RÉAUMUR, a grave error would be committed, which analysis teaches one to avoid. There exist, in fact, two distinct kinds of devitrified or crystallized glasses, resulting from different actions. 1. The first class embraces glasses which, by means of a prolonged heat, and sometimes by the aid of a suitable lute or cement, *have arrived at a state of homogeneous combination, and have taken the crystalline form, losing some of their constituent principles.* 2. The second kind comprises glasses which, by means of a solidification very slowly effected, *are divided into two or more different compounds, some of which have preserved the uncrystallized state, while others have taken a regular crystalline form.*

It is possible to discover by analysis what takes place in these two cases. The manner in which RÉAUMUR effected the devitrification has been already stated. In proceeding to examine its results, DUMAS made the following analysis of a tube of bottle-glass devitrified by M. D'ARCET at the glass-work of La Garre at Paris:—

	Centesimally.	Oxygen.	
Silica,	52·0	= 27·0	
Alumina,	12·0	= 5·6	= 7·6
Sesquioxides of iron and manganese,	6·6	= 2·0	
Lime,	27·4	= 7·6	= 7·8
Loss, or potassa,	2·0	= 0·2	
	100·0	42·4	

Comparing this analysis with that of common bottle-glass, already given at page 191, it will be seen that the amount of the potassa is reduced to at least one-third or a half of the ordinary quantity. Moreover, this analysis shows that the sample analysed consisted of one equivalent of sesquisilicate of iron or of alumina, and one equivalent of bisilicate of lime or of potassa.

It is far from probable that the same result would be obtained for all analogous glasses, as regards the state of saturation of the silicates, or their proportion to each other; but it is certain that the potassa almost entirely volatilizes by the devitrification effected in RÉAUMUR's manner, and that the other products arrange themselves, either to constitute a single silicate, or to form several of them, which remain mingled.

D'ARCET found, it is true, that bottle-glass was devitrified without changing its weight. That might happen, in fact, when the oxygen, absorbed by the transition from the oxide of iron to the sesquioxide, is equal in weight to the potassa volatilized.

The chemical changes observed in the devitrification of *bottle-glass* consist, therefore,—1st. In the loss of a part or the whole of the potassa. 2nd. In the passing of a part or the whole of the protoxide of iron and of manganese to the state of sesquioxides. 3rd. In the formation of one or more definite and crystallized silicates, by means of the remaining products.

The second process of devitrification, which consists in the mass being broken up into different chemical compounds, presents itself sometimes alone, but often simultaneously with the preceding. DUMAS mentions the curious results of an experiment made on the large scale, at the glass-works of Choisy-le-Roi, in which this process was observed to be quite distinct from the preceding. A glass was formed with 100 of sand and 40 of carbonate of soda, perfectly pure and dry. This glass being cooled rapidly, was transparent like ordinary glass. It was re-melted, and submitted to a slow cooling, that the solidification might take place tardily. A glass was thus obtained which was milky, grainy, and evidently devitrified in some places. The devitrified parts were re-melted, and rapidly cooled again after the melting, which furnished common glass once more. This glass, by a new fusion and a prolonged cooling, gave a glass better devitrified than it was the first time. Lastly, the portions which exhibited the most perfect devitrification, being again melted and quickly cooled, again yielded a glass endued with its ordinary characteristics.

This remarkable experiment sufficiently proves that, in the slow solidification of glass, a division of its elements is determined, in consequence of which a definite silicate crystallizes, and thus separates from the remaining mass.

DUMAS states that there existed in the cabinet of the Polytechnic School at Paris, a mass of glass detached from the bottom of a crucible. At the surface of it was an opaque crust, white, crystallized in needles, and of a uniform thickness of one or two lines. All the rest of the mass was of a perfect transparency, but in the interior of it might be observed a multitude of white and opaque prisms, similar to the exterior crust: partly isolated; partly collected in groups of two, three, four, *et cetera*, and forming stars; in some cases more numerous still, and then forming spheroids. The devitrification was therefore effected in this case at the surface, in consequence of the evaporation of the potassa, and in the mass itself, in consequence of the separation which resulted from a slow cooling. Subjoined is the analysis of the two kinds of glass contained in this piece by DUMAS, and that of another specimen by KERSTEN:—

	Kersten.				Dumas.			
	Crystalline portion.		Vitreous portion.		Crystalline portion.		Vitreous portion.	
		Oxygen.		Oxygen.		Oxygen.		Oxygen.
Silicic acid,	58·8	30·54	60·39	31·40	68·2	35·46	64·7	33·64
Alumina,	3·3	1·54	6·10	2·84	4·9	2·28	3·5	1·63
Lime,	20·2	5·77	13·40	3·83	12·0	3·43	12·0	3·43
Protoxide of iron,	3·5	0·80	3·10	0·70	—	—	—	—
" manganese,	4·2	0·93	2·20	0·49	—	—	—	—
Magnesia,	0·5	0·19	0·40	0·15	—	—	—	—
Potassa,	2·7	0·45	14·41	3·05	—	—	—	—
Soda,	5·5	1·40			1·49	3·81	19·8	5·06

It is evident that, in the specimen analysed by DUMAS, the potassa had been separated from the glass at the instant of crystallization. It is equally manifest that while no simple proportion can be traced between the elements of the transparent glass, one observes, on the contrary, in the crystallized glass a clear and well-defined composition; for the oxygen of the alumina is about one-third of that of the potassa and of the lime, and the oxygen of these three bases is pretty exactly the fourth of that of the silica. It is, therefore, a compound of one equivalent of quadrisilicate of alumina, and of three equivalents of quadrisilicate of soda or of lime, which corresponds to the composition of ordinary window-glass. More distinctly, in the specimen analysed by DUMAS, the oxygen in the silicic acid is to that of the alumina, and to that of the other bases together, in the following ratios:—

In the crystalline portion, as 35·46 : 2·28 : 7·24 = 18 : 1 : 3
In the vitreous matrix, as .. 33·64 : 1·63 : 8·49 = 15 : 1 : 5

For the former, ... M_2O_3, $6 SiO_3 + 9 (MO SiO_3)$
For the latter, ... M_2O_3, $3 SiO_3 + 15 (MO SiO_3)$

In the specimen analysed by KERSTEN, the relations of the oxygen were as follow:—

In the crystalline portion, as 30·54 : 1·54 : 9·54 = 21 : 1 : 6
In the vitreous matrix, as .. 31·40 : 2·84 : 8·22 = 12 : 1 : 3

For the crystalline portion, . M_2O_3, $3 SiO_3 + 9 (MO SiO_3)$
For the vitreous matrix, ... M_2O_3, $SiO_3 + 18 (MO SiO_3)$

These relations, as deduced from both analyses, render it probable that the two portions were distinct chemical compounds. It may, therefore, be assumed that when the glass is submitted to a slow solidification, there occurs a separation of the least fusible definite compound to which its elements can give rise—the latter then taking the crystalline state.

If the analyses of different glasses previously given had not solved the question, these last two would suffice to demonstrate that all the glasses are silicates in definite proportions, or, at least, mixtures of different definite silicates, dissolved the one by the other. Hence it may be inferred, that by sufficiently prolonging the time of the solidification of a vitreous mass, it would be possible to separate successively compounds more and more fusible, the alkaline base concentrating more and more in the successive residues. And hence, also, may be conceived what takes place in the solidification of lavas, which have so much analogy with the products now under consideration, and an explanation may be given of the formation of natural crystals, so diversified as they appear in their mass.

To sum up—in the words of DUMAS, to whom the Editor is chiefly indebted for what has been stated on this interesting subject—*devitrification is a crystallization of glass, due to the formation of definite compounds infusible at the temperature existing at the instant of the devitrification.* Sometimes this infusibility is produced by the volatilization of the alkaline base; sometimes by a simple division or separation, the alkali then passing into that portion of the glass which preserves the vitreous state. All glasses may therefore be devitrified, for all glasses are capable of passing to the state of definite, and consequently crystallizable, silicates. Glasses which contain at the same time indifferent oxides and basic oxides will devitrify better than others, by the tendency which the indifferent silicates and basic silicates have to combine in definite proportions. Lastly, devitrified glasses will possess very variable properties, for their composition itself will differ completely, according to the nature of the glasses and the circumstances of the devitrification. Thus, sometimes the devitrified glass will be crystallized in needles of considerable size, as happens with window-glass; sometimes it will be crystallized in very fine needles, or even simply transformed into an opaline mass, without appearance of crystals, as in the case of bottle-glass.

Specific Gravity of different kinds of Glass.—It is evident that the specific gravity of glass must depend on its composition. Alkaline calcareous glasses are the lightest; bottle-glass comes next; then plumbiferous glasses. The following are the results of some experiments:—

	Specific Gravity.
Bohemian glass,	2·396
Crown-glass,	2·487
Saint Gobain plate-glass,	2·488
Cherbourg plate-glass,	2·506
Window-glass,	2·642
Bottle-glass,	2·732
Crystal, or common flint-glass,	2·9 to 3·255
Optical flint-glass,	3·3 to 3·6

The Editor finds several kinds of glass to give the following specific gravities:—

White flint-glass,	3·000
Bottle, common green,	2·715
Green-glass, St. Helen's,	2·654
Crown-glass,	2·520
Leith crystal,	3·189
Plate-glass, Ravenhead,	2·439

As regards crystal or flint-glass, the density may suffice to give a pretty exact idea of its composition. It is not so with the other kinds of glass, the differences of density of their constituent principles not being sufficiently marked.

LOYSEL attempted to establish formulæ which might permit of passing from the density to the composition, but they are altogether inapplicable. Little, if any, advantage is to be had from them, even for glasses containing lead. These relations vary from so many causes, that, to establish them in a positive manner, it would be necessary to limit oneself to certain glasses, and to deduce them from experiments so delicate and so numerous, that it would be better to have recourse to the ordinary methods of chemical analysis, the results of which will always be more reliable.

CHEMICAL PROPERTIES OF GLASS.—Among the chemical properties of glass, there are some which merit an attentive examination. DUMAS classes them as follows—namely, the effect of the air or of deoxidizing bodies; that of water; that of acids; and that of bases.

Action of Air or Oxygen.—Air or oxygen, cold or hot, provided they are dry, exercise no action on glasses. It is not so with moist air, as will be seen further on, especially with reference to soluble glass. In this case, however, the reagent is water.

Action of Deoxidizing Bodies.—It is evident that deoxidizing bodies may, on the contrary, act with the aid of heat on glasses which contain oxides of iron or of manganese, and especially oxide of lead. In fact, when plumbous glasses are heated with charcoal, or in a current of hydrogen, they very readily undergo a remarkable alteration. The oxide of lead is reduced, and the metal being set free, communicates to the glass a blackish tint. This effect is even so rapid, that one cannot operate on crystal at the enameller's lamp without blackening it greatly, except particular precautions be used. The plan which succeeds best consists in placing a little soap on the wick of the lamp; the flame suddenly assumes a different appearance, and no longer blackens the crystal. It is probable that the presence of the soap affects the capillarity of the wick, and diminishes the ascent of the oil.

Action of Water.—Water does act more or less on all glasses; and there is a great number which it tends to decompose into a soluble alkaline silicate, and an insoluble earthy and alkaline silicate. It produces in some sort the same separation which would result from a slow cooling, or from the devitrification of the glass. Window glasses, or those which have an analogous composition, are altered in this manner, and very much so, by boiling water. This was long ago remarked by Scheele. So much is this the case, that water which is boiled for a long time in glass vessels becomes alkaline and turbid by the portion of earthy and insoluble alkaline silicate which forms the residue of its action, and which, detaching itself from the sides of the vessel, remains in suspension in the liquid. This effect is even so marked on crown-glass, plate-glass, and certain window glasses, that it is only necessary to reduce them to a fine powder, and to put them in contact with cold water, in order to impart to the water an alkaline reaction. Lastly, these same glasses have almost always so much of a hygrometrical property, as to become covered with a thin coating of water when they are exposed to the contact of moist air.

This action of water affords an explanation of a considerable number of phenomena occasionally observed on glasses, and chiefly on those with a base of lime and soda, or potassa. Every one knows that looking-glasses sometimes tarnish in the air. This result proceeds from the deposit of a film of hygrometrical water; the same is observed on the glasses of optical instruments. If the glass is well made, the effect proceeds no further; but if it is too alkaline, the deposited water gradually acts upon its surface, and thus produces a decomposition similar to that above-mentioned; in this case the glass is tarnished beyond remedy, or at least it must be repolished. Sometimes the tarnishing is scarcely perceptible, and yet a great alteration may have been produced on the surface. This is observed when one proceeds to heat the glass; its surface becomes detached in very thin lamellar scales, presenting a great regularity of fracture. The glass then remains completely deprived of its polish, wrinkly, and almost opaque. Glass-tubes, globes, retorts, and even measures or standing-glasses, which in laboratories are long exposed to moist air, very often exhibit the same phenomena. In this state the tubes, for example, can no longer be heated at the lamp without losing their polish. Watch-glasses are often observed in the same condition, and even the glasses of optical instruments. It appears, indeed, that glasses which have been polished are more liable to this effect than common glasses. It is well known that glass which has not been polished presents a harder and more brilliant surface, which seems due to the *tempering* it undergoes at the instant of cooling. It is possible, therefore, that polishing renders glasses more readily attacked, by exposing the interior part of the mass, and destroying the hard coat which secured it.

The windows of houses, offices, or public buildings, of an old date, often present a tarnished and unpolished surface, the origin of which must be attributed to a similar cause. When the hygrometrical water has attacked the glass, the slightest changes of temperature cause its surface to splinter, which thus becomes dull, devoid of polish, or at least cracked, and disposed to rise in scales by the least rubbing. This effect may especially be remarked in the windows of stables; these, after some years, are always so much altered as to exhibit all the phenomena of the decomposition of light produced by thin plates; they become in fact irisated, and sometimes in a manner very remarkable for the intensity and purity of the colors. This, however, is chiefly due to the ammonia, developed by the recrement and urine of the animals, attacking the silica. On the contrary, it is the weather or moisture which produces the remarkable alteration observed in old glass that is found in ruins or in tombs. Its surface is sometimes entirely decomposed; it has become opaque, and the slightest rubbing causes it to peel off in thin light pellicles, exhibiting all the colors of the rainbow. When the decomposed part is detached from the outer surface of a phial, one would suppose it to be cut: but it is not so: this appearance is due to the interior layer of the decomposed glass, which, by reason of its perfect opacity, reflects all the light which passes through the part still transparent. One finds here, therefore, but only in greater intensity, all the effects which may be so frequently observed on stable windows.

Action of Alkalies.—Since water *per se* is capable of acting on glass with so much energy, it will readily be conceived that *concentrated solutions of potassa and soda* must be capable of attacking it still more powerfully. This kind of reaction has not been much studied. At a red heat, not only potassa and soda, but all the carbonates and all the bases of that class, combine with the elements of glass to constitute glasses more basic. When carbonate is used, the carbonic acid is expelled. It may even be said that all the oxides not decomposable by heat, when heated with glass, combine with it, and thus form glasses transparent or opaque, colored or colorless, more or less readily acted on than the glass employed, according to the proportions. In general, when the proportion of oxide added is much increased, the glass is rendered soluble in acids. This is what is done in the analysis of glass, when it is heated with carbonate of soda, carbonate of baryta, or oxide of lead.

Action of Acids.—The acids, in their turn, should act on glasses with facility. Among these, the hydrofluoric acid must be classed by itself, its action being quite peculiar. The other acids tend to decompose glass, by seizing on the bases and setting the silica free.

Among the bottle-glasses, there are many which resist the action of wine, and which, nevertheless, are powerfully attacked by the nitric, hydrochloric, and sulphuric acids. Salts of lime, of iron, of alumina, and alum, are formed when sulphuric acid is used. This acid produces in the interior of the bottles crystalline nipples or pustules, the base of which ultimately pierces the vessel; these pustules are sometimes of the size of a bean; in all cases the silica set free assumes a jelly-like appearance.

A bottle-glass too rich in alumina is one of those which the acids most readily attack. Dumas states that he has seen such glasses, which the bitartrate of potassa contained in the wine attacked so quickly that the alteration was perceptible at the end of a few days.

The salt of alumina produced discolors the wine, and imparts to it a disagreeable taste. The bottle becomes corroded, and a flaky deposit is detached from it. At the same time, crystals of different salts are deposited.

Glasses with a lead base are so much the more easily acted on in proportion as they are too rich in lead. Well-made crystal resists acids well. It is the same with window glasses; when too alkaline they are acted on very easily; when well-made, they resist. Moreover, when a glass loses its polish by heat, one may be sure that it is of a nature to be attacked by acids.

Special Action of Hydrofluoric Acid.—It has been stated that the hydrofluoric acid acts on glass in a special manner; and indeed, as this acid transforms the silica into water and fluoride of silicium, it follows that it must act on all glasses. Its action in fact would be always quick and complete, if the formation of a certain quantity of double fluoride of silicium and sodium, of potassium, or calcium, or lead—double fluorides, which are all insoluble, or only slightly soluble—did not diminish the contact, and, consequently, the effect produced.

The hydrofluoric acid, however, attacks glass rapidly when the action is exerted on a small surface, and much acid is employed. This property has been turned to account to etch glass; the acid is employed in a gaseous or liquid state, according to the occasion and the end proposed. The gaseous acid produces opaque traces; the liquid acid transparent ones. But the subject of etching on glass will be alluded to afterwards.

MANUFACTURE OF GLASS.—There are no reliable records of the processes employed by the ancients in the making of glass. But from the time when AGRICOLA described this art, the general arrangement of the furnaces, the mode of fabrication, and the nature of the materials employed, have undergone only modifications of detail, without any change in the general character of the process. No inconsiderable portion of works on the manufacture of glass is usually devoted to the arrangement and construction of the furnaces and pots, the tools employed by the workmen, and the dexterous mechanical operations by which the soft and ductile *metal* is shaped into the various forms that fit it for domestic use and the purposes of science and the arts. These subjects form so important a part of the glass manufacture, that they cannot be entirely omitted in the present work; but the Editor deems it his duty to discuss them as briefly as possible, devoting his principal attention to the chemistry of the manufacture. He will therefore dismiss, in a very few words, the construction of the furnaces, pots, and tools employed.

Glass-house and Furnaces.—The glass-house in which the processes of melting and blowing are performed, is usually built in the form of a truncated cone, open at the top, of sixty or eighty feet in height, and forty or fifty feet in diameter at the base. In the centre of the area is situated the melting furnace, capable of holding from five to ten glass-pots or crucibles for fusing the materials. The grate of the furnace is nearly on a level with the floor of the glass-house; and the ashpit or *cave* is a subterranean passage, extending from each side of the furnace to the exterior of the building, so as to catch the wind from as many aspects as possible. The particular arrangements of the glass-house, and the construction of the furnaces, are somewhat varied according to the kind of glass prepared.

The plan of a flint-glass-house furnace is shown in the annexed engraving—Fig. 137—where the furnace is represented as containing ten pots, E E. There are as many flues, B B, as pots, one flue being placed between every two pots; and immediately abreast of each pot, and between two flues, is an aperture called the working hole, which is used for introducing the raw materials, and taking out the glass or *metal*. The coals are shovelled through a square hole, D, upon the grate, C C, in the centre of the furnace. The grate bars are supported by two strong iron sleepers, and are protected from the intense heat by being previously covered with a layer of clinkers or potsherds; but, as the furnace attains its maximum heat, sufficient clinkers are formed to serve the purpose. All round the grate-room a bank, A, is raised, termed the *siege*, on which the pots are placed, so that the fire lies, as it were, below the bottom of the pots, and in the centre of the furnace. The sides of the furnace are a little higher than the top of the pots, and the arch or crown is made as low as possible to be consistent with durability.

Fig. 137.

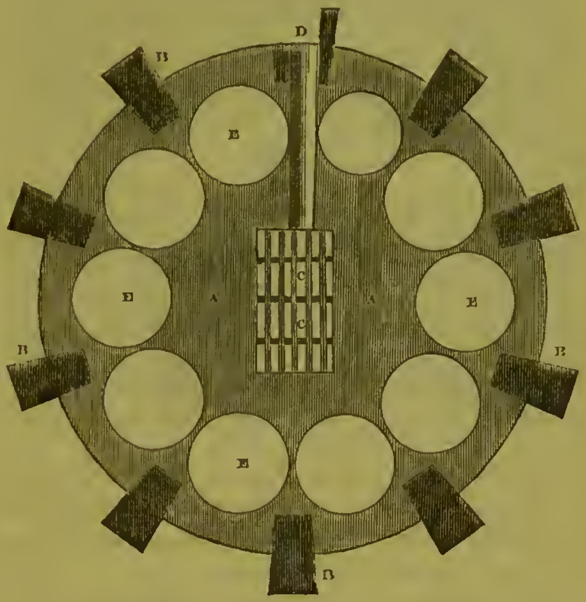
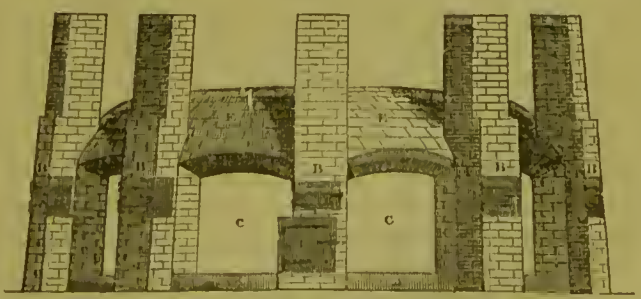


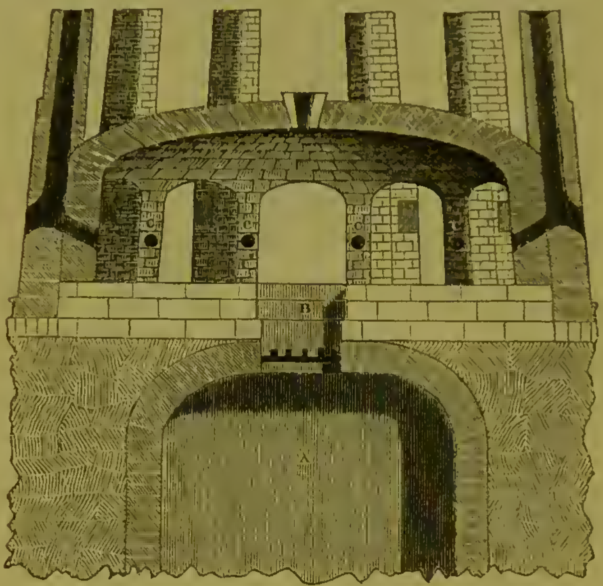
Fig. 138 is an exterior view of the brick dome, and Fig. 139 an interior sectional elevation of the same, showing the position of the flues, arches, and cave. In Fig. 138, the letters A A indicate the sole of the furnace; B B, the flues; C C, openings or arches, which, after intro-

Fig. 138.



ducing the pots, are built up, leaving only working holes; D is the door for introducing the fuel; and E the roof or dome. In Fig. 139, A is the cave or air-tunnel below the furnace; B, pit of furnace, with grates below;

Fig. 139.



C C, flue or linnet holes, through which the flame, not being allowed to issue from the centre, passes up the flues, discharging into the brick dome, and from thence into the funnel and chimney shaft.

The dimensions of a convenient flint-glass melting furnace are given by Mr. Apsley Pellatt as follows: —A furnace for ten pots of thirty-six inches diameter is twelve feet seven inches in interior diameter, including the flues; the height to the inside of the dome is four and a half feet; each of the arches is three feet one inch by three feet three and a half inches to the highest part. The fire is regulated by the stoker or *teazer*—from the French, *tiseur*—who can raise the heat of the furnace to the highest pitch by opening holes at the bottom of the grate. A ten-pot furnace consumes from eighteen to twenty-four tons of coal per week.

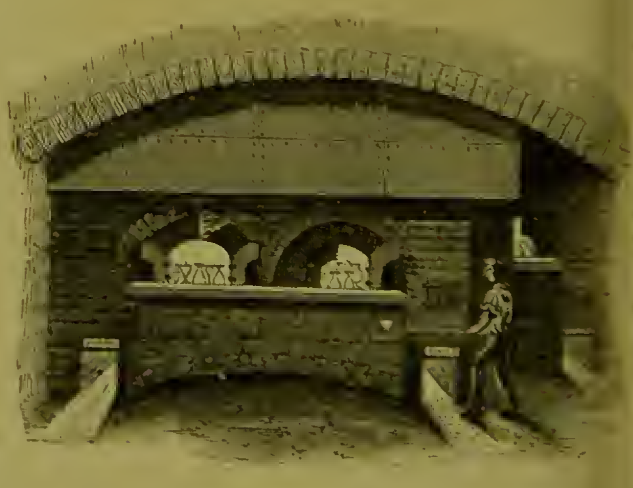
Richardson and Ronalds remark, that the construction of the melting-furnaces in a glass-house is attended with many difficulties, against which it is almost impossible to provide; and the wear and tear becomes a serious item to the manufacturer. The prevailing temperature of a glass furnace, about 20·000° Fahr., presents in itself a serious difficulty; but in cases where open pots are employed, this is materially increased by the volatility of the alkalies, which amounts to nearly twenty-five per cent. of the potassa. The binary compound of silicic acid and alumina becomes changed into a ternary one, through the action of the alkali when clay is employed, and into a silicate of potassa or soda where firestone is substituted; in each case a fusible compound results, which rapidly wastes away, and at last, both pots and furnaces become too much corroded for use. In ordinary cases, three years is the usual duration of these furnaces, except in flint-glass-houses, where they last longer, from the lower melting point of the materials, and the peculiar shape of the pots.

The sides of the furnace are constructed of bricks, formed in moulds made for the purpose. The best fire-clay, mixed with the remains of old pots coarsely ground, is the material employed for making these bricks; but these clays would be much improved for this and many other purposes, by the addition of some coarse sand, or ground pure sandstones. The roof is generally made of sandstone alone, of a coarse grit, and very porous. No cement is employed in the arch, the expansion of the stone, and the partial fusing of the interior surfaces afterwards, bind the whole sufficiently well together.

The crown and plate-glass furnaces are similar to the flint; they are placed also in the middle of the cone, but contain only from four to six pots, each of the capacity of half a ton of metal.

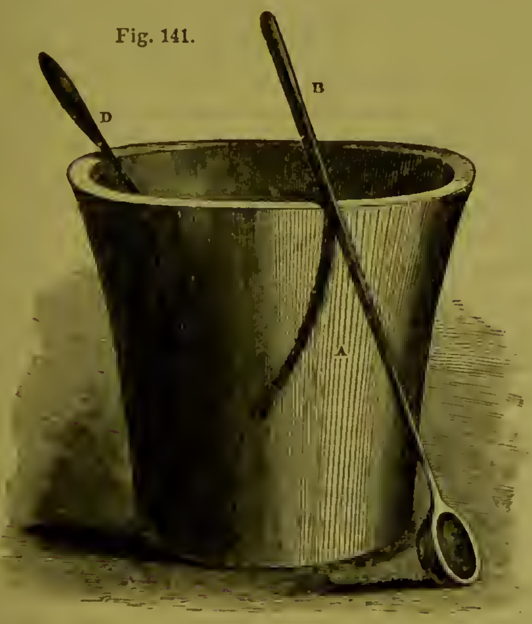
Besides the main or melting furnace, a glass-house contains a variety of furnaces and arches adjoining or around the inside of the cone, for different subsidiary operations. The *calcar arch*, for burning frit, now little used, is a common reverberatory furnace, about ten feet long, seven feet wide, and two in height. In crown-glass works there are also the *blowing furnace*, the *bottoming hole*, and the *flashing furnace*, besides an aperture in the latter termed the *nose-hole*. The uses of these will be explained in connection with the crown-glass manufacture. Lastly, the *leer* or annealing oven is one of the most important appendages of every glass-house. This is the name given to a low arch, open at both ends, in which the manufactured goods are allowed to cool gradually. The arch is usually about sixty feet in length, five feet wide, and not more than from one to two in height. Adjoining the door or receiving end is a small furnace on each side, by which the temperature at that end is maintained just short of a melting heat; but, as there is no other heating power, the arch or oven experiences less and less of the heat as the distance from the mouth is greater, until, at the remote or discharging extremity, the temperature is scarcely higher than that of the atmosphere. There are usually from two to four of these annealing arches placed side by side, as represented in the above engraving, Fig. 140. Along the floor of each is a miniature railway, upon which two rows of iron

Fig. 140.



trays, called *leer pans*, travel from the hot to the cooler end, where they are taken out. The pans are moved slowly along the leer by means of an endless chain, or sometimes they are gradually pushed forward by the trays last put in. The fuel employed is coke, which imparts the most regular heat for annealing, and is the freest from smoke, the carbon of which, when coal is used, injures the color of the glass. The time required for proper annealing varies from six to sixty hours, the weighty articles requiring the most heat and time. The hotter the goods enter the arch the better, and on this account large articles, before being introduced, receive a final re-heating at the mouth of an empty pot, heated by beechwood, and called the *glory-hole*. Much of the success of annealing depends on the proper direction of the wind, which ought to pass over the fuel of the leer toward the leer chimney at the cooler end, so that the hot air may always radiate in the downward current upon the goods. When an upward or contrary current of wind drives back the heated air from the cool or chimney end toward the fuel at the upper end, where it comes into contact with the hot articles just introduced, great losses from breakage often occur.

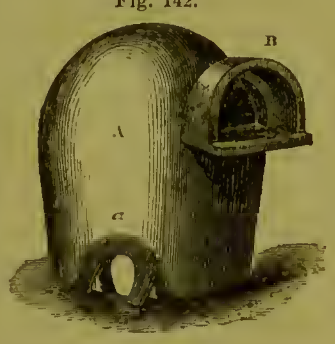
Fig. 141.



Kilns, which differ from leers in being closed at the further end, were formerly in general use for annealing goods intended for deep cutting, the kilns, when filled, being carefully closed up along with the burning fuel. The time required for cooling in this case was usually about a week. To avoid so much delay, the kilns have been superseded by the use of iron covers or a bedding of sand in leers; also by lengthening the leer fire-places, and not filling the pans with glass too quickly.

The Pots.—The crucibles, or pots, in which the vitreous mixture is melted, require every care to be taken in their preparation. Those used for bottle, crown, and plate-glass have the form of a truncated cone, A—Fig. 141—the narrow end being the base. Their depth is usually four feet six inches; their diameter at top, from four feet to four feet six inches, and at the bottom, about three feet four or six inches. In the same figure are shown the ladle, B, for taking out the glass, and the stirring rod, D. The pots for flint-glass are hooded or covered at the top, and have a mouth, B, in front like a muffle, as shown in Fig. 142; but those for crown, plate, and bottle-glass are open. The horse-shoe-shaped piece of fire-clay, *a*, is inserted in the mouth during the melting, to diminish the aperture.

Fig. 142.



Fine clay is the material of which the glass-pots are made, and it must be as pure and refractory as can be obtained, free from every trace of lime in any state, and sulphide of iron; and the less oxide of iron the better. The kind of slate clay dug out of the coal formation near Stourbridge, which contains very little, if anything, besides silicic acid and alumina, is decidedly preferred to all other compounds found in this country. The clay is mixed with varying proportions of the remains of the old pots, and the *tempering*, or previous preparation of the mixture, requires great attention. A certain quantity of the ground materials, after being mixed with water, is stored away in large wooden bins or receptacles, and turned over from time to time, during which a workman treads it under his naked feet. This *kneading* of the clay renders it very uniform and free from particles of air. The following is the composition of some of the clays employed:—

	Stourbridge. Richardson.			Editor.	
				Stourbridge.	Rhuabon.
Silicic acid,	68·05	63·70	64·10	63·99	61·77
Alumina,	18·85	20·70	23·15	20·84	18·97
Lime,	·80	1·30	—	·30	1·53
Magnesia,	—	—	·90	·94	·91
Iron,	5·10	1·00	1·85	·75	·17
Water,	6·00	10·30	10·00	11·67	14·79
Loss,	1·20	3·00		1·51	1·86

The proportions given by Barruel as most suitable for glass-pots of any description, are thirteen parts of crude aluminous clay, twelve parts of calcined silicious clay, and three parts of the remains of old pots. The last-mentioned material assists the more regular drying of the pots, and renders the whole body more porous, and less liable to crack by heat.

When the mass has been kneaded three times over until it acquires a pasty consistence, it is rolled into small pieces about the size of a sausage, and these wet rolls are placed together upon a wooden or leaden slab, to the thickness of four inches, to form the bottom. It is then turned up at the edges, and built, layer above layer, in successive rings, all formed by the eye of the workman, without the use of a mould. When the pot has been finished, the sides are made smooth by means of small wooden scrapers.

After the glass pot is formed, it is allowed to remain for a considerable time in an apartment heated by a flue to a little above the ordinary temperature—about 80°—in order that it may be slowly dried in an equal manner throughout its whole thickness. Two or three years is the time allowed by some manufacturers for this gradual desiccation.

Before the pot is *set* in the furnace, it must be subjected to an annealing process, which consists in gradually increasing its temperature during several days to bright redness. This is usually done in a reverberatory constructed for the purpose, the fire in which must be raised very slowly, not more than a shovelful of coals being introduced at a time, and that at regular intervals. While at a bright red or even a white heat, the pot is quickly transferred, with the assistance of adequate machinery, into its seat in the hot furnace; a part of the face of which must be pulled down, to allow of the ready extraction of the old pot, and introduction of the new one. Before the pot is used, it is *glazed*, as it is technically termed, before being filled with materials; that is, some cullet or old glass is thrown into it, and spread over the sides in a molten state. This penetrates to the depth of a few lines into the substance of the pot, and forms a hard, difficultly fusible enamel, which protects the pot from the further action of the substances added.

The setting of a new pot is a very arduous undertaking, and is generally attended with great excitement, and even danger, on account of the intense heat to which the workmen are exposed. It is generally performed at the end of the week when the work of the glass-house is slackened, and all hands are required to be present to assist at the operation.

A good pot-maker, says Mr. Henry Chance, with two assistants, can furnish three or four pots per week. After a careful drying of many months, they are made ready for the furnace, as has been stated, by a previous heating in a kiln or pot-arch. Here a small lump of coal, thrown against its side, tests the soundness of the pot. If, when struck, it rings well, its future is promising; but if it returns a dull sound, it will probably be short-lived in the furnace, though now and then such a pot will disappoint the bad opinions formed of it, and turn out a respectable pot after all.

The terrible task of setting these pots in the furnace, continues Mr. Chance, falls upon the glass-house crew, and the nicety with which these enormous vessels are adjusted in their place, in the teeth of a consuming fire, is, perhaps, that operation which, in the many marvels of glass-making, would most astonish a stranger to such scenes. The average duration of the pots, when thus fixed, is about seven weeks. Some attain the age of ten or twelve; while others, as every manufacturer well knows, terminate their existence prematurely, either from the naturally defective constitution of the pot, or from bad treatment in the pot-arch, or more frequently from its having been *starved*—that is, exposed to a current of cold air in the furnace, through the neglect of the attendant. The breakage of a pot often disturbs the furnace to such an extent, that the breakage of others frequently follows, and many weeks will sometimes elapse before the disorganization thus produced can be rectified. The loss of the pot and the contained *metal* is nothing as compared with the injury which the glass in the surviving pots, and these pots themselves, are apt to sustain.

Crude Materials for Glass-making.—The chemical or theoretical composition of the different varieties of glass has been already given at pages 191 and 192; but as it is quite impossible to obtain or prepare the ingredients in a state of chemical purity previous to fusing them together, it will be necessary to explain the sources from which the materials that go to constitute the different glasses are practically derived for the purposes of the manufacture.

Silica.—It has been stated that all true glasses are practically composed of silica, or silicic acid, in combination with at least two alkaline or earthy bases, and sometimes oxides of lead, zinc, and other metals. Silica, silicic acid, or teroxide of silicium—$Si\,O_3$—is the principal ingredient. It is very abundant in nature, forming a principal constituent in rocks and stones, and existing in a free and almost pure state in flint, agate, chalcedony, rock-crystal, and quartz, the last two being its purest form. Formerly, flint—*silex*—calcined and ground, was used as the source of the silica, and hence the name of *flint-glass*. Sand, however, is now employed as the most general and economical source of silica, and renders the process of grinding unnecessary. At the same time the great variations in the purity of this material render requisite a careful selection for the different kinds of glass, and the manufacturer must choose such as the microscope and analysis show to be most suitable for his purpose. The finest English sands are from Alum Bay in the Isle of Wight, and Lynn on the coast of Norfolk. The French obtain a very superior sand from the forest of Fontainebleau, in the neighborhood of Paris; and Mr. H. Chance justly remarks, that to the purity of this and their other materials the superior color of their glass may be partly ascribed.

The sand, being always more or less impure when brought to the glass-works, is conveyed to an upper room, and thrown into a trough of water, where it is carefully washed. It is then placed in a trough over an oven, and, when partially dried, passes through holes into the oven. When quite dry, it leaves the oven in the state of fine, glittering white particles, like powdered quartz. These precautions are not necessary for bottle-glass.

Potassa and Soda.—The alkalies used in the manufacture of common colored glass, such as those used for green bottles, are obtained, as far as the potassa is concerned, from common *ashes*, and the soda from the *ashes of sea-plants*, or refuse soda. Better kinds of glass are made with crude potassa and soda-ash, and the best from purified potassa and soda-ash. Not more than thirty years have elapsed since crown and sheet glass were manufactured from the crude alkali obtained from kelp, the preparation of which for this purpose employed a large population on the Northern shores of Scotland and West of Ireland, and the abandonment of this material, when the duty was taken off barilla, plunged whole districts into idleness and misery. The kelp was used simply in combination with sand—the kelp containing soda and potassa, and furnishing the necessary amount of lime; but the glass thus produced was of very variable, and often most inferior quality. The discovery of LE BLANC in 1792, which effected the conversion of common salt into carbonate of soda, was the commencement of a new era in the history of Continental flint-glass; but the introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates only from the year 1831. Ultimately sulphate of soda was substituted, except for plate-glass, the manufacturers of which still adhere to the carbonate. The black bottles of Newcastle are made from common rock-salt, and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary. The carbonate of potassa is obtained chiefly from Canada and the United States, and requires a process of washing previous to use. The state to which it is brought by the process of cleansing is that of fine white grains, differing but little, to an unpractised eye, from the prepared sand.

Lime.—This substance, which forms an important constituent in flint-glass, may be introduced either as a carbonate, or slaked or burned. Limestone, however, that contains proto-carbonate of iron, must be excluded from the mixture for making white glass. The action of lime is to render the alkaline silicates insoluble, and when rightly balanced by the other ingredients, it promotes the fusion of the whole, and improves the quality, but when added in excess, the glass becomes hard and difficult to work, and subject to devitrification.

Lead.—The next substance in point of importance is lead, which forms the distinguishing ingredient in crystal or common flint-glass, optical glass, and strass. These glasses are fused from a mixture containing litharge—PbO—or minium—red lead, Pb_3O_4. Of these two compounds, the latter is preferred on account of its finer state of division, its pulverulent form, and because it is decomposed in the glass-pot into ordinary protoxide of lead and oxygen, which latter oxidizes, and removes many impurities, as, for example, charcoal. An excess of lead acts injuriously upon the melting vessels, and, besides inducing too great softness in the glass, gives it a yellow tinge.

Baryta.—This substance, in the form known as *heavy spar*—BaO, SO_3—is sometimes added to the constituents of common bottle-glass, to render it more easy of fusion.

Alumina.—The sesquioxide of aluminum—Al_2O_3—though seldom purposely introduced into glass, is always accidentally present, brought there by the action of the materials upon the clay of the pots in which they are melted. Alumina, if present in any quantity, is always an undesirable ingredient, as, by increasing the number of silicates, it renders the glass more liable to devitrification, it being well known that the more compound a glass is, the more does it display this tendency. Hence, bottle-glass, which contains a greater variety of bases than any other, is of all the most easily devitrified.

Iron.—Another unwelcome element is iron, which is almost always present in the sand, in the sulphate of soda, when employed, and in the chalk, partly in the state of protoxide, the coloring effect of which is partially destroyed by other ingredients, to be afterwards mentioned.

Arsenic.—A little arsenic promotes the decomposition of the other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of; but, in excess, it produces a milkiness in the glass, which time will increase.

Cullet.—Another substance is added—abundantly produced in every manufactory of glass—namely, a quantity of waste glass, or cullet, which, being more fusible than the raw materials, facilitates the melting. For this purpose, the waste glass in the glass-house, and that collected in the neighborhood, are carefully sorted, cleaned, ground, and incorporated with the mixture *for similar kinds of glass.* Great care must, however, be taken that no broken glass of an inferior kind is mixed with the ingredients for finer glass. The cullet not only incites fusion, but materially aids the union of the bases with the silicic acid.

Decoloring Materials.—It has been stated in the historical notice that every description of glass exhibits a tendency to color, which probably led to the idea of stained glass. This tendency is more or less developed, even when proper proportions and the purest materials for the mixture have been employed; and as any tinge is considered a defect in white glass, or that which is employed for windows and particularly in the finer kinds of glass, certain materials are employed with the special object of counteracting it. To this class of substances belong *binoxide of manganese*, *arsenic*, already mentioned, and *nitrate of potassa.* The accidental elements which usually color the glass are *iron* and *carbon*, or carbonaceous matters, and in all cases the substances above-mentioned are employed to neutralize or counteract these by means of *oxidation.*

For example, if particles of carbon or soot from the fire or flame become mixed and surrounded with the melted glass, these, by their exclusion from the access of air, are prevented burning, and a brown or nearly black color is produced, which is removed by the conversion of the carbon into carbonic oxide through the influence of the oxidizing or decoloring material. The manner in which manganese acts on the protoxide of iron has been already explained—page 189—and is similar to its action on carbonaceous matters, which are thus removed in a gaseous form from the melted mass. A few ounces of the binoxide of manganese are, therefore, usually added to the materials for making flint-glass, which is always required in a state of great purity; and, from the cleansing action of this material, it has received the familiar title of *glass-makers' soap.* It must, however, be used sparingly; for an excess of it produces a compound of silicic acid with sesquioxide of manganese, which communicates a lilac or amethystine color to the glass. The approved remedy for this, when the error has been committed, is to stir up the colored mass with a wooden pole, which reduces the sesquioxide to the protoxide, and the lilac color disappears.

Some manufacturers use manganese, on account of the reddish tinge it imparts to glass, expressly to disguise the bad green or yellow color produced by the other materials. In this case two tinged glasses are formed, which mask each other's defects, the green and red rays combining together, as supplementary colors, to transmit white light. Indeed, in plate-glass for fine windows, a slight excess of manganese is sometimes allowed, expressly to produce a delicate amethystine tint, which improves the complexion of persons who receive the light of day through the window.

Smalt, a blue glass, is sometimes used, like manganese, to mask the bad color produced by the other materials. Properly speaking, however, the decoloring agents are those which act by oxidizing the carbon or the protoxide of iron, and thereby actually expelling the lime. In this way nitrate of potassa reacts before the glass enters into perfect fusion; arsenious acid, arsenic acid, and their salts, exert their action at a temperature above the fusing point, and are volatilized.

Glass from Felspar.—The making of glass by means of felspar is an idea which naturally suggests itself to the mind, when one considers the ready vitrification of this mineral, and was suggested even long ago by M. Ghérard in the memoirs of the Academy of Berlin. According to this authority, the following mixture is proper for a window-glass, namely, two parts felspar, two parts sand, one part chalk, which would give, for the composition of the glass, supposing no volatilization of the potassa during the melting, nearly the following:—

	Centesimally.
Silica,	73
Alumina,	8
Potassa,	7
Lime,	12
	100

These ill-calculated proportions could only give a glass difficult to melt, and prone to devitrify. This, says Dumas, is exactly what happened in an experiment made on the large scale by M. Rey, under the eyes of Chaptal and Allut. The melting required a twice longer time than the usual, but it furnished a beautiful glass. The experiment was supposed to be a fortunate one; but when the crucible was cooled sufficiently to admit of the working of the mass, it was found quite opaque, milky, and clotty—in fact, devitrified. Must felspar, therefore, be renounced? It is difficult to admit this. If a mixture be made of one hundred parts of felspar, one hundred parts of Arcueil clay, or some analogous clay, and eighty of quicklime, or its equivalent in chalk, a glass of the following composition will be produced:—

	Felspar.	Clay.	Glass	Or centesimally.
Silica,	66	63	129	46·3
Alumina,	18	37	55	20·0
Potassa,	16	—	16	5·7
Lime,	—	—	80	28·0
			280	100·0

—that is to say, a glass which, if the clay is free from iron, would be quite of the same nature and color as bottle-glass, and which would present advantages as well as disadvantages. As regards common window-glass, or analogous glasses, felspar should be capable of entering into these in the proportion of one-third or one-fourth, without serious disadvantage. A glass would be produced which would differ from common glass only by the presence of four hundredths of alumina, and glasses are met with in commerce which contain this quantity and even more. Lastly, it is probable that by suitable additions of borax, boracic acid, or oxide of lead, one might get felspar itself to produce a glass endued with all the desirable qualities.

Glass from Volcanic Products.—Dumas remarks that certain lavas, pumices, pitchstone, and other volcanic products, approach so closely to bottle-glass in their composition, that the possibility of turning them to account in this way cannot be doubted. The merit of the first attempts of this kind is due to Chaptal; and if these attempts did not succeed, this must be attributed to the time at which they were made, rather than to the idea itself, which is both good in theory and must be capable of succeeding in practice. The analyses will be sufficient to prove this:—

	Lipari pumice.	Basalt of Hasenburg.	Basalt of Staffa.	Pitchstone of Misnia.
Silica,	77·5	44·5	48·0	73·0
Alumina,	17·5	16·7	16·0	14·5
Oxide of iron,	1·7	20·0	16·0	1·0
Soda, Potassa,	3·0	2·6	4·0	1·75
Lime,	—	9·5	9·0	1·0
Magnesia,	—	2·2	—	—
Water,	—	2·0	5·0	8·5
Hydrochoric acid,	—	—	1·0	·25
Loss,	·30	2·5	1·0	·25
	100·0	100·0	100·0	100·0

With pumice-stone, forge-scoriæ, chalk, and a little soda in proper proportions, bottle-glass might therefore be made. Basalt would require only the addition of a little chalk and soda. Pitchstone treated like pumice-stone would furnish it also.

The trials made by the directions of Chaptal succeeded so far as the matter examined by him was employed; but when another volcanic product came to be used, the results were bad, the proportions being deranged. A very simple analysis would have prevented all trouble, and would have preserved their proper rank to these volcanic matters, the excellent effects of which have been demonstrated by a sufficiently long experience.

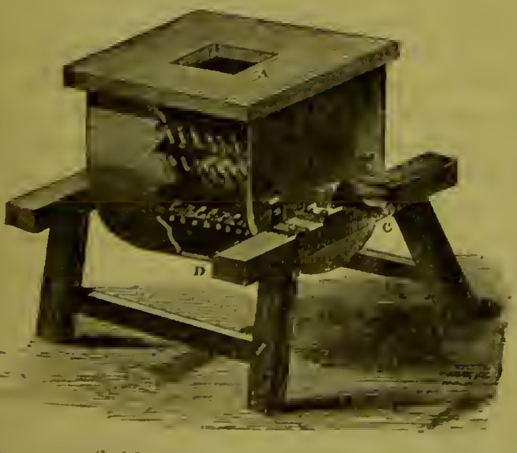
It was in 1780 that Chaptal, then Professor of Chemistry at Montpellier, proposed the use of lava. M. Ducros, a glassmaker in the environs of Alais, melted, with coal, the lava of the extinct volcano of Montferrier, without any addition, and made some bottles of it. M. de Castleviel, another glassmaker of the country, melted, with wood fuel, a mixture of sand, lava, and soda, and thus produced bottles lighter and stronger than those usually manufactured. These bottles had such great success that the demand could not be supplied. But at the expiration of four years, the bottles which were produced no longer resembled the first ones: they were much inferior; the manufactory lost its reputation, and was compelled to abandon the system which it had just tried with so much success.

The nature of the lava, therefore, had changed, and the same proportions being no longer suitable, an analysis alone could have guided the operator. It is with this that the process must be commenced, if it is intended to resume a manufacture, worthy, in so many respects, of being submitted to trials which the state of science would now render much easier. It was in consequence of taking a different course that M. de CASTLEVIEL failed, and that M. FOUGEROUX de BONDAROY, who appears to have been occupied in 1787 with the same subject, without any knowledge of the preceding facts, succeeded no better.

THE FUEL.—The fuel formerly employed in England in the making of glass was exclusively *coal*, but of late it has been found that, in London especially, many advantages result from using *oven-burned coke*, which produces less smoke and soot, and is, therefore, much better adapted for the finer glasses. Some glass-houses have all the requisite accommodation for making coke. In France both coal and coke are employed, and sometimes *wood;* but BARRUEL states that wood has been generally abandoned as being more costly, and producing less heat than coal, so that with the former the fusing and refining of the metal require longer time. In Germany *wood* is generally employed, and in some few places *peat*. Even the best air-dried wood would fall far short of producing the desired effect, in consequence of the amount of water which it still retains, and therefore it has been the practice on the Continent, from a very ancient period, to bake the air-dried wood in a particular kind of furnace until it begins to become brown, or until the whole of its water has been volatilized. Peat when used in the glass-house must be perfectly dry, and afford only a small amount of ash.

PREPARATION OF THE MATERIALS.—A great saving of time and fuel is effected by carefully grinding and intimately mixing the materials previous to the melting. For this purpose edge-stones and coarse sieves are essential in a glass-house. Until quite recently, the mixing and sifting were always performed by hand, and the operation was therefore imperfectly performed, the mixture so produced being little calculated to favor those chemical changes and mutual reactions of the materials which are necessary to the formation of a homogeneous fluid transparent body. To obviate this disadvantage, a mixing apparatus, especially intended for crown-glass, has lately been contrived by Mr. CHANCE. This very simple machine, which is shown partly in section in Fig. 143, is made entirely of wood, and consists of a semi-cylindrical chamber, with an opening, A, at the top, for introducing the materials, and another in the semicircular bottom at D, through which they are removed; B is a cylinder in which a number of oblique beaters are fixed, and the whole is made to revolve by a handle or by a shaft from the steam-engine connected with the axis, C. Mr. COOPER applied with the best effect a simple revolving wooden barrel, similar to those employed in the powder factories. The composition, when mixed, is termed *batch* or *frit*—the latter word being derived from the circumstance, that during the period when barilla, kelp, and other forms of crude alkali were in use, it was the custom to subject the materials to the preliminary operation of *fritting* or stirring them together under the heat of a reverbatory furnace, thereby effecting partial decomposition, and burning off any carbonaceous impurities; but the introduction of alkali prepared from common salt has, in most cases, removed the necessity of this treatment. One great advantage of fritting consisted in the partial union which it effected between the silicic acid and the bases, so that the latter were not volatilized in the furnace previous to the formation of the glass, and the pots and sides of the furnace were consequently less exposed to the injurious action of their vapors. With the purer materials now employed in the manufacture, the advantages gained by the operation are not generally considered sufficient to compensate for the loss of fuel incurred in producing the high degree of heat required to perform it.

Fig. 143.



MELTING.—The raw materials, consisting essentially of sand or silica as the base, and alkali as the flux or solvent, having been thoroughly incorporated with a suitable proportion of cullet or broken glass of the same kind, are introduced by means of a clean iron shovel into the melting-pot, which has been previously raised to a white heat. But the whole of the mixture is not introduced at once, for the mass of glass which a pot will hold occupies before fusion, in the state of frit, just twice the space of the melted glass. Not more than one-third of the mixture is therefore introduced at first through the working holes, the temperature is then raised to the maximum, and as the mass subsides by melting, a fresh quantity is introduced, until the pot is filled with melted glass. During the whole period of the melting or *found*, the stokers or *teazers* keep the furnace well supplied with fuel, so as to prevent any portion of the grates becoming uncovered, in which case a rush of cold air from below might split some of the pots. At the same time the *founders*—from the French, *fondeurs*—are engaged in noting the progress of the fusion, by taking from time to time proofs or drops from the pots, by means of a short rod, flattened at one end, and examining if any undissolved grains of sand are perceptible on refrigeration, and whether the mass, which still contains a quantity of air-bubbles, appears uniform throughout. So long as carbonic acid is evolved in abundance, or during the *boil*, the mass is agitated by the escape of the larger bubbles of gas in a manner most favorable to the operation, this motion answers the purpose of stirring, and mixes the compounds of variable degrees of fusibility and density, which are at first produced, with each other; at a later period, when the disengagement of gas ceases, the denser compounds are apt to settle down at the bottom of the pot, where the temperature is about one-fourth lower, and is, consequently, incapable of preventing the deposition by the production of ascending currents. This evil is moderated on the Continent by stirring with the scooping ladle, or by thrusting a piece of arsenious acid to the bottom of the pot, and thus causing a forcible expulsion of vapor from that part of the vessel. At the close of the melting process, the contents of the pot are not by any means pure, or equally mixed. All the solid matter is dissolved, but the mass of glass is full of small vesicles of gas, presents a spongy rather than a dense appearance, and is not yet in a state fit for working. The surface is also covered by a layer of so-called *glass-gall* or *sandiver*, a melted mixture of salts, which have not been volatilized, nor combined with silica during the process of melting, and consisting chiefly of chloride of potassium—or sodium—and sulphates, which in consequence of imperfect vitrification have escaped decomposition.—*Knapp.*

The following, says RICHARDSON and RONALDS, has been found to be the composition of this saline matter, glass-gall or sandiver, which is skimmed off the surface of the melting materials, and is technically termed *salts:*—

Constituents.	German plate glass.	Crystal-glass.	Bottle-glass.
Water,	1·65	·10	1·00
Sulphate of soda,	83·32	90·51	55·92
Sulphate of lime,	10·35	6·00	25·11
Chloride of sodium,	1·43	·04	·20
Carbonate of soda,	trace	—	—
Potassa,	—	—	trace
Insoluble matter,	3·25	3·35	17·77
	100·00	100·00	100·00

Glass-gall, when occurring in large quantity, is removed with ladles, and is employed on the Continent by saltpetre and alum manufacturers, or workers in bronze; in the varieties of glass prepared from purer or purified materials, where, instead of crude potassa, ashes, or soda, purified substances have been employed, either no glass-gall is produced, or that which appears is easily removed by volatilization.

FINING.—For some time the glass does not become transparent, the opacity being due to bubbles of air or gas, and to the lime and earthy impurities which do not fuse. The object of the *fining*, which is the last process in glass-making, properly so called, is the removal of these by the subsidence of the heavier particles to the bottom and the escape of gas at the surface. For this purpose the glass must be brought to the most fluid state possible, and the heat is therefore raised and sustained for some hours at the highest point. In Germany this part of the process is termed *heiss-schüren*, or *hot-covering*. In forty or forty-eight hours after charging, the vitrification is complete. When all the gas-bubbles have passed off, and the sandiver has become transparent and colorless, the temperature of the pot is lowered by diminishing the draught—a process termed *kalt-schüren*, or *cold-covering*—the object of which is to bring the glass from a state of nearly perfect fluidity, in which it could not be worked, to that free viscid or plastic condition necessary for the working. For this purpose the bars of the furnace are plastered up. The great thickness of the walls, and the slow combustion of the fuel, which is supplied in moderate quantity, keep the furnace hot enough to retain the glass in a workable viscid state during the period in which the glass is blown or otherwise shaped into the required forms.

The reactions which take place in the pot or crucible are very easy to understand. For example, if the silica has been mixed with carbonate of soda and carbonate of lime, the silica, at a high temperature, seizes on the soda and lime, and the carbonic acid is disengaged. In the same manner, if silica has been mixed with carbonate of potassa and minium, this last returns to the state of massicot, and the silica then combines with it and the potassa. There is, therefore, in this case, first a disengagement of oxygen, then an elimination of carbonic acid.

These evolutions of gas which constantly accompany the production of glass, explain the presence of the *air bubbles* already mentioned as so frequently observed in the vitreous mass. To expel these, it has been stated that the temperature must be raised very high, that the glass may become quite fluid. But as the potassa and soda may be volatilized at this high degree of heat, one is obliged to introduce into the compositions much more potassa and soda than the glass is intended to retain.

This elevated temperature is also necessary in all cases where impure alkalies are used. The presence of the chlorides, and even that of the sulphates which melt without mixing with the glass, would occasion in the latter a multitude of white and opaque nodules disseminated through its mass. At a high heat both of these matters, being lighter than the glass, rise and float on the surface, constituting the principal portions of the glass-gall or sandiver above alluded to. It must be stated, however, that ever since the salts of soda have been sold at a low price, and are consequently generally used, very little glass-gall has been produced in the manufacture of the ordinary kinds of white glass; but in bottle-works this impurity always occurs, because crude sodas are employed.

FAULTS IN THE GLASS.—Notwithstanding all the precautions that may be taken, air-bubbles frequently remain, and generally exist in great number when the fining process has been obstructed by too great difficulty of fusion in the glass. They are technically termed *seed*, *blibe*, or *blister*.

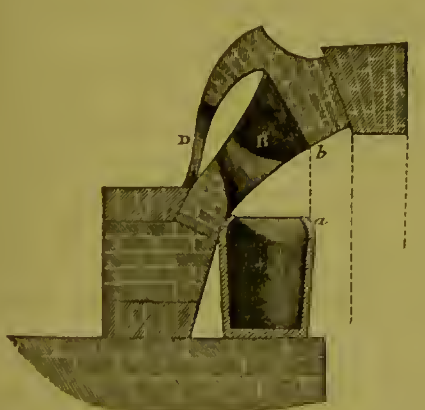
Two further accidents to which the glass is liable are known as *threads* or *strings*, which are generally contracted during the blowing, when cold particles of glass drop into the viscid or imperfectly melted metal, and not having time to undergo fusion remain hard, and appear as unsightly projections from the blown vessels.

Waves and *striæ* are faults of too common occurrence, arising from a want of homogeneity in the vitreous mass. The latter of these terms is applied to the effect produced when the density of the glass, in consequence of imperfect fusion, is not uniform throughout, and all the parts, though equal in transparency, do not refract the light equally; and consequently, images of objects seen through the glass appear out of place or distorted. This fault is very objectionable in plate-glass for mirrors or windows, as well as in crystal or flint-glass for optical purposes. *Waves* are superficial and protuberant striæ, which always occur when the glass is blown too cold.

A not less serious evil, which is frequently a source of color in the glass, arises from the action of the alkaline vapors upon the constituents of the sides or roof of the furnace, particularly when chloride of sodium or sulphate of soda is used in the manufacture. The volatilization of the alkali, whether soda or potassa, produces over the pots a rapid vitrification of the bricks of the vault, and hence drops of *colored glass*, known by the name of *tears*, which occasionally fall into the pots. These are produced by the silicic acid of the bricks combining with the alkali, and forming with it, and with the iron and alumina of the clay, a green and very infusible glass, which sinks to the bottom of the pot from its greater density, leaving in its course a fibrous tail which remains in the glass. Imperfections of the same kind are produced, though less frequently, by the action of the glass upon the walls of the pot itself.

According to KIRN, the drops of aluminous glass may be prevented from falling into the pots by constructing the latter and the arch of the furnace in the manner represented in Fig. 144. In this case the portion of the wall of the furnace, which comprises the working hole, B, is made so large that drops, falling perpendicularly from any protuberance or irregularity, *b*, can only reach the exterior of the inflected margin, *a*, of the pot, A; and the size of the working hole is reduced to the proper dimensions by a second less solid arch, D. Another plan, mentioned by KNAPP, is to make the working hole in the perpendicular wall of the furnace, and to spring the arch of such a form that the angle of the part over the pot may be sufficient to cause the *tears* to flow down the arch instead of dropping into the pot.

Fig. 144.



WORKING TOOLS AND APPARATUS.—The tools represented by BLANCOURT, in his work *On the Art of Glass*, which was printed at London in 1699, are almost precisely the same as those now in use; and the author's account of their mode of working might almost be taken as a description of the modern process. To those curious on the subject, BLANCOURT's description is well worthy of perusal.

The most important of these instruments is the *pipe*, on the end of which the glass is taken up by the workman, and blown into spheres or bulbs, to be subsequently shaped into different forms, as will be afterwards described. A section of this indispensable instrument is shown in Fig. 145. It is simply a tube, composed of wrought-iron, four to five feet long, one inch thick, and about one quarter to one inch in the bore. It is provided with a knob at each end, the one of which, *a*, serves as a mouth-piece, whilst to the other, *b*, the melted glass is attached. The upper portion is surrounded by a wooden cover, *c*, to protect the hands of the workman from the heat of the metal. A companion to this instrument is a solid iron rod, known as the *pontil* or *ponty*, which serves to receive the glass after it is blown on the pipe. The *spring-tool*, A—Fig. 146—is a species of tongs for laying hold of half-formed handles, and for seizing the glass while making. The *pucellas*, B, have prongs resembling the cutting part of shears, but blunt, and are used for rubbing the outside of solid or hollow glass, and pressing it into smaller diameter, at the same time elongating the parts by rotation. The battledore, C, is made of wood, and is used for flattening the glass when necessary. The shears, D, are strong scissors for cutting and shaping the edges and handles of glass vessels while in a soft state. The fork, E, is employed for carrying the finished articles to the annealing oven.

Fig. 145.

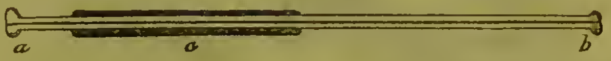
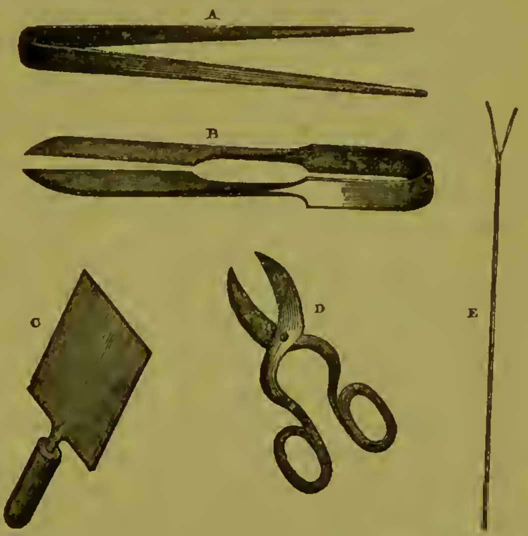
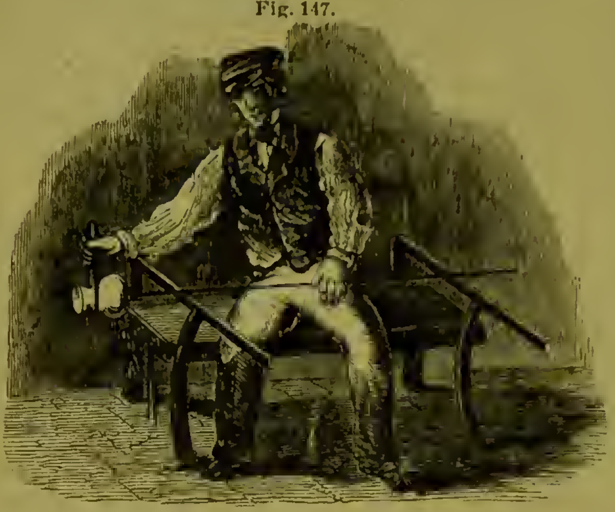


Fig. 146.



An important part of the glass-blower's furniture is the *marver*, which consists of an iron plate or slab, resting on a stone or on wooden supports, and having a polished surface, on which the mass of glass that has been gathered at the end of the blowing tube is rolled, to give it a symmetrical form. The term *marver* is derived from the French *marbre*, a marble slab being formerly used. The *glass-maker's chair*—Fig. 147—is a flat seat of wood, about ten inches wide, each end of which is fixed to a frame connected with four legs and two inclined arms, upon which is screwed an edging of wrought-iron for rolling the blowing tube with the hot glass backwards and forwards with the left hand, while the required form is given to the glass with the pucellas held in the right.

Fig. 147.



Continual rotation of the melted mass is the principal point to be attended to in most of the glass-blower's operations; but these will be best described in connection with the special manufacture of the different varieties of glass.

SPECIAL MANUFACTURE.—A visit to the glass-house will convey a much more vivid idea of the beautiful art of the glass-blower, and the wonderful material with which he works, than the most elaborate written description or pictorial illustrations. There is, moreover, so much of the *mechanical* connected with the fabrication of glass, that great part of it does not properly fall within the scope of this work. In proceeding, therefore, to describe the details of the different departments of the manufacture, the Editor will dwell as briefly as possible on those operations which do not involve the application of chemical agencies.

The arrangement to be followed will be somewhat similar to that already indicated, as adopted by Knapp, but with some important modifications—beginning with the coarser or commoner qualities, and rising by a natural gradation to the finer and rarer kinds of glass manufactured for optical lenses or ornamental purposes. On this principle, the following arrangement will embrace all that is necessary:—I. Ordinary or Green Bottle-Glass. II. White Bottle-Glass, including *refractory Bohemian and Foreign crown.* III. Window-Glass, embracing—1. *English crown,* and 2. *Sheet* or *cylinder glass.* IV. Plate-Glass, with the process of silvering mirrors. V. Crystal or Common Flint-Glass, and Optical Flint-Glass. VI. Strass and Colored or Stained Glass. VII. Soluble Glass.

I. Green Bottle-Glass.—The materials for common glass bottles are coarser and cheaper than for any other kinds of glass; and, in consequence of this very coarseness or want of refining, the elements which enter its composition are more numerous, consisting, as already stated, of silica, lime, potassa or soda, oxides of iron and manganese. These last oxides communicate a color to this glass, which owes, at the same time, a part of its characteristic hue to the charcoal. Indeed, as the color of bottle-glass may be considered as essential to it, or at least does not injure its sale or diminish its value for the purposes to which it is applied, no decoloring materials are used, and it is melted in open pots, even when coal is used as the fuel, which is always the case in this country. The omission of decoloring materials forms the distinguishing feature in the manufacture of ordinary bottle-glass.

Materials.—The English laws, till lately, prohibited the use of fine materials for making ordinary bottles. Nothing but the common river sand and soap-boilers' waste was allowed. About three parts of waste, consisting of the insoluble residuum of kelp, mixed with lime and a little saline substance, were used for one part of sand. This waste was first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it was kept at a red heat, with occasional stirring, from twenty-four to thirty hours, being the period of a journey or *journée*—a day—in which the materials could be melted and worked into bottles. The roasted soap-waste was then withdrawn, under the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture was now put into the fine arch, and calcined during the working journey, which extended to ten or twelve hours. Whenever the pots were worked out, that frit was immediately transferred into them in its ignited state; and the founding process proceeded with such despatch, that this first charge was completely melted down in six hours, so that the pots might admit to be filled up again with the second charge of frit, which was founded in four hours more. The heat was briskly continued, and in the course of from twelve to eighteen hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification was complete.

At the present time, in choosing ingredients for bottle-glass, economy is the chief object; color and appearance are here of no moment. Little soda or potassa is admitted into the composition of this description of glass; and, as the carbonates of these bases are costly, it is usual to employ in the bottle glass-works only recent ashes or wrack-soda to furnish the alkali. Moreover, the other materials are taken in a state of impurity fit only for bottles.

The primary materials of the manufacture of this kind of glass are yellow and ferruginous sands, residues proceeding from the lies of the soap and soda works, lixiviated ashes, common ashes, wrack sodas, and clay.

The colored sands are even preferable to white sands for bottle-glass, the oxide of iron, which colors them, performing the part of a flux. They do not require any washing or other preparation; nevertheless, any coarse foreign substances, such as pyrites, flints, *et cetera*, are separated from them. For this purpose they are dried, and passed through a sieve. The clay best adapted for bottle-glass is a yellow marly earth; it is furnace-clay, containing, therefore, alumina, silica, carbonate of lime, oxides of iron and manganese; it has not much of a binding quality, and is easily reduced to powder when dry, which facilitates the mixtures.

The ashes are generally obtained from common domestic fires. Those are preferred on the Continent which proceed from the combustion of new wood or charcoal. They are sifted and dried before using. The wrack-soda is employed in a powdered state; it is even passed through a very close wire sieve.

The following is given by Dumas as the usual proportion of these materials:—For

ORDINARY FRENCH BOTTLE-GLASS.

30- 40	pounds	varec.
160-170	,,	lixiviated ashes.
30- 40	,,	fresh ashes.
80-100	,,	clay containing iron.
100	,,	broken glass.

The proportions in English bottle-glass are slightly different:—

ENGLISH BOTTLE-GLASS.

100	pounds	lixiviated ashes.
40- 90	,,	kelp.
30- 40	,,	wood-ashes.
80-100	,,	clay.
100	,,	cullet.

The amount of cullet is not particular; it is increased for the first and second melting, when new pots are used. If a very argillaceous sand is employed, it is necessary to suppress the clay, and supply lime by a suitable addition of chalk. Natron or crude soda may be used to replace the potassa yielded by the varec; but in this case care is taken to add to the mixture a certain quantity of fresh ashes, that the glass may not be wanting in potassa.

The proportions given in the preceding recipes, as well as in those that follow, are calculated for one hundred pounds of sand:—

FOR CHAMPAGNE BOTTLES, ACCORDING TO JAHKEL.

200	pounds	felspar.
20	,,	lime.
15	,,	common salt.
125	,,	iron slag.

ORDINARY GREEN BOTTLE-GLASS.

72	pounds	lime.
280–278	,,	lixiviated wood-ashes.

DARK GREEN BOTTLE-GLASS.

20	pounds	dry Glauber's salt.
18	,,	soap-boilers' flux.
1	,,	Scheffel—Pruss.—lixiviated ash.
39	,,	glass from the hearth.
179	,,	green cullet or broken glass.
45	,,	basalt.

Melting.—The melting-furnace for bottle-glass commonly contains only six pots. These are about three feet in height, and nearly the same in diameter. They are filled almost to the edges; and when the matter has sunk down, and is converted into a glass, more of the composition is put into the pots, and the fire is urged. The meltings are rapid; for as most of the bottle-glass compositions furnish but little glass-gall, no time is lost in fining. The process lasts from seven to eight hours, and, when it is concluded, the fire is slackened, that the glass may thicken to the point suitable for working it. For this purpose the fire-place is heaped up with small coal, draughts are intercepted as much as possible, and care is taken not to touch the fire during the working of the glass, lest the combustion should be re-excited.

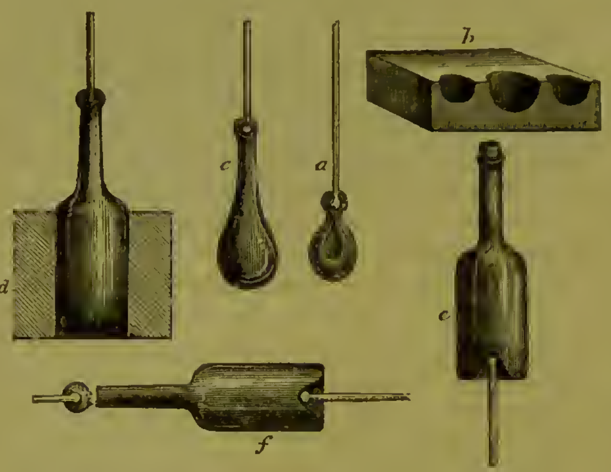
Mechanical Operations.—The working or shaping of bottle-glass is very simple in principle, and yet the operations involved are somewhat complex in detail. These may be summarily stated as follows:—The assistant collects or *gathers* on the end of the pipe—Fig. 145—the requisite body of glass, and passes it to the blower. The latter, by blowing and constantly turning the pipe, gradually forms the body of the bottle, which is finished in a mould. While the bottle is in the mould, the workman continues to blow and to turn. He then raises the pipe, and, holding the bottle in a vertical and reversed position, he depresses or hollows the bottom. The bottle is then cut at the neck, and the iron rod termed the ponty fixed at the opposite end of it; the edge of the neck is rounded, and the ring or cord which encircles it is put on, as also the seal, if the bottle is intended to have one. The ponty then passes into the hands of the assistant, whose duty it is to carry it to the annealing furnace. He there detaches it from the rod by a slight blow.

Such are the chief operations of the process of bottle-making, as described by Dumas; but as this manufacture affords a good instance of the dexterous manipulations which are practised in blowing glass, a subject deeply interesting to the practical chemist, the following more detailed account, which is given by Knapp as descriptive of the mode of working carried on in Spessart, will be not unacceptable to the reader:—

As soon as the working holes are opened, and the surface of the glass is cleared from sandiver or glass-gall, the workman attaches as much melted glass to the end of the pipe as he considers necessary for the production of a single bottle; his eye and hand are here unfailing guides as to the requisite quantity. By dipping the previously warmed pipe into the pot, a little glass remains attached to the end; after turning this in the air before the hole until it is cooled, and blowing slightly into it to render it hollow, a fresh layer of glass may be attached to it in the pot; to this, a third is added in the same manner, until the ball at the end of the pipe has accumulated to a sufficient size, *a*—Fig. 148. That this ball may become uniformly tractable in the subsequent forming, it is held by the workman in the flame of the furnace through the working hole; it is then brought into one of the round concavities of the *marver*, *b*, which is wetted or moistened when used. Here the ball gradually assumes the form of a thick hollow globe, or rather pear-shaped vessel. It acquires this shape by the constant rotary motion given by the workman to the pipe, whilst the cooling and stiffening of the mass is rendered uniform by the marver, and is prevented shrinking together by constantly blowing into the tube with very little force. The mass of *metal*, which, as already stated, is the technical term applied to glass during working, must be equally distributed round the axis of the instrument, and advanced in front of its mouth, being connected with it only by a short neck. Towards the front part, where the subsequent widening occurs, and the mass is blown out, it is thickest; the portion nearest the pipe is less massive.

Thus far advanced, the glass has again become cool, and is re-heated by insertion into the working hole, in such a manner that the front part receives the chief portion of the heat, and becomes the softer. The pear-shaped vessel is now lengthened by the blower, and its form is made somewhat to resemble that of a bottle by a threefold operation: by blowing into the tube with greater force, *swinging* it backwards and forwards in the manner of a pendulum, and by a simultaneous constant rotary motion of the pipe round its axis. The globular form which the glass tends to assume under the influence of blowing, is converted into a long, thin egg-shape, *c*, by the swinging motion, and so much the more as the lower temperature at the extremity is less favorable to the formation of a globe, than to the lengthening of the neck. The rotation round the axis of the pipe is an essential part of every operation in glass-blowing. The glowing mass of glass creates a powerful current of air in an upward direction, and the lower portion becomes cooled in consequence much more than the upper. This naturally creates an inequality in the resistance offered to the blowing, and the upper portion would be more expanded than the lower, if the cooling influence were not allowed to act upon all parts of the surface alike, by the revolving motion of the pipe, and this is particularly the case when the latter has to be held in a horizontal position. The mould, *d*, which is a simple cylindrical hollow block of wood or iron, is placed at the side of the workman who is blowing the pear-shaped vessel; into this he inserts the vessel as soon as it has acquired the proper thickness, in the manner represented in the figure, and by blowing forcibly into the tube, he presses the glass firmly against the sides of the mould, whilst, by a kind of jerking motion, the neck is drawn out to the proper length. The unfinished bottle, which as yet has no bottom or mouth, is again warmed in the working hole in such a manner, that the lower part only is heated, whilst the other part remains comparatively cool. In the meantime, another workman or a boy has attached a small quantity of glass to the ponty or pontil, which is also kept hot in the working hole. Both workmen now stand opposite to each other; and whilst the pipe and ponty are kept constantly turning, the latter is forcibly pressed against the middle of the lower part of the bottle, which is thus forced inwards, and an even edge is produced, upon which the bottle may stand steadily. The bottle remains for some moments between the two instruments, as shown at *f*, until, by the application of cold iron or a drop of water, the neck can be separated from the pipe. This is an operation of constant recurrence in the glass-house, and is effected by a sudden change of temperature produced at the point of separation in the hardened glass, either by the cold application of a drop of water, or by the powerful heat of a red-hot iron, or thread of liquid glass from the pot. The point of separation must often be re-heated, to cause it to fly on the application of cold water. The bottle is now supported by the ponty, as shown at *e*, so that the neck can be warmed, and the sharp edges melted round without softening the other parts. A rotating motion is then given to the red-hot neck, the pipe being rolled backwards and forwards upon the knees of the workman. The bottle then revolves upon its axis, as if it were placed in a lathe, and it is only necessary to press the pucellas, B—Fig. 146—or an iron instrument like a turning chisel, against the mouth, to widen or reduce it to any required dimensions; the rim for strengthening the neck is formed from a drop of glass taken from the pot by the edge of the flask, and wrapped round the mouth in the form of a thick thread. The bottle, which is now finished, as shown in the last cut, is immediately carried on the ponty-rod to the annealing-oven by a boy, pushed into its proper place, and the ponty-rod is finally detached from the bottom of the bottle by a sudden sharp jerk. The place where the ponty was attached is perceptible in every bottle blown in this manner, by the sharp edges where the fracture occurred.

Fig. 148.



Large round bottles are blown without the use of a mould, and when of a very great size, like the carboys for sulphuric acid, the aid of steam is called in, by spirting about an ounce of water into the interior, and holding the mouth of the pipe with the thumb. Bottles in the shape of a flattened globe, are also made without any mould by simple blowing. The preparation of the mass of glass, the formation of the concave bottom and of the neck, is in this case effected in precisely the same manner as above; the swinging motion, however, must not be continued for such a length of time, as the bottles required are shorter. In blowing the belly of the bottle, the workman stands in front of a slanting board and presses the globe, as it is gradually formed by slow blowing, against the board at every half revolution of the pipe; the flat surfaces on opposite sides are thus produced.

As the greater number of bottles are necessarily sold with a legal stamp upon them, and as their capacity must be suited to the standard measures of the country, the fulfilment of these conditions presupposes an extraordinary degree of dexterity and correctness of eye in the blower. Attempts have consequently been made by many inventors to furnish the bottle-maker with a mould of such construction as would enable him to secure the formation of a bottle, perfect, both as regards form and capacity, at one single operation, without reliance upon his own correctness of sight. The use of moulds of this description, like that of Ricketts, which is easily managed, affords a great saving of time, and the repeated heating of the bottles is unnecessary. The mould consists of a body, which forms the belly of the bottle, and of four other parts, a fixed bottom-piece with a movable piston for forming the concavity, and two movable pieces for the neck. Two treadles set these different parts in motion. As soon as the workman has introduced the hollow lengthened globe into the belly of the mould, by pressing with his foot upon the first treadle, he brings up the neck piece, then forces the glass into contact with all parts of the mould by a powerful blast, and finishes the bottle by working the second treadle, which forces the pestle against the bottom. On the removal of the pipe, the rim is all that remains to be perfected.—*Knapp.*

The circle of operations above described is continued with much quickness, four or five men being able to make a hundred wine bottles in an hour; and, with a few modifications, according to the size, shape, and purpose of the bottles, may be taken as a general exemplification of the mode of proceeding. The vicinity of the Tyne on the Wear is abundantly supplied with many of the requisites for bottle-making, and hence the manufacture is there largely carried on.

Champagne and Aerated Water Bottles.—The uses of bottle-glass do not require to be explained in detail, but it is necessary to say a few words with reference to bottles intended to resist a high pressure, such as those for holding champagne, and still more in this country for holding aerated waters, which are now manufactured in immense quantities. Bottles employed for such purposes undergo an internal pressure, which readily produces the fracture of weak vessels, and this occasions a loss which is always considerable, and often disastrous. It is evident that this might be diminished by testing all the bottles under a pressure the double of that to which they are intended to be subjected, and accordingly different machines have been invented for this purpose, by means of which water is forcibly pumped into the bottles, until the indication of the manometer shows them to have withstood a sufficient degree of force. DUMAS states that, from the experiments made by the *Societé d'Encouragement*, champagne bottles were found to stand only when they were capable of supporting a pressure of twelve atmospheres. He adds that the mode of filling and annealing, as well as the form of the bottles, must exercise a great influence, which it would be necessary to find the means of estimating; also, that perhaps it would be desirable to leave a larger unfilled space in the bottles, and to use them only after a careful annealing in boiling water. KNAPP remarks, that although every bottle, when quite filled with water and containing no air, will burst in the belly from a slight blow on the cork, in consequence of the sudden force being communicated from the liquid to the sides, yet champagne bottles will often withstand a pressure of forty atmospheres and upwards, equal to six hundred pounds on the square inch.

II. WHITE BOTTLE OR CHEMICAL GLASS.—Under this head may be included white glass for medicinal bottles and chemical purposes, refractory Bohemian glass for tubing, *et cetera*, and foreign crown. The most beautiful material for bottles is furnished by flint-glass or crystal, but these are only intended for ornamental articles or vessels for the table, and will be alluded to under Flint-glass.

The general character of white bottle-glass consists in this, that it is composed of purer materials than the green; decoloring matters are used, and the materials are selected as free from iron and alumina as possible. Moreover, in this case the glass is subjected to a thorough fining process. The following are given by KNAPP as general standards of composition for different varieties of glass of this description:—

FOR APOTHECARIES' PHIALS.

100	pounds	white sand.
30– 35	"	potassa—impure.
17	"	lime.
110–120	"	ashes.
·25–·5	"	binoxide of manganese—cullet.

BOHEMIAN CRYSTAL FOR GRINDING.

100	pounds	white sand.
0– 60	"	purified potassa.
8	"	chalk.
40	"	broken glass.
·75	"	manganese.

SEMI-WHITE.

100	pounds	sand.
100	"	crude soda, containing lime.
100	"	cullet.
·5– 1	"	manganese.

100	pounds	sand.
30	"	potassa.
18	"	lime.
	decoloring matters.	

CLEAR WHITE.

100	pounds	sand.
65	"	calcined potassa.
6	"	fallen lime.
100	"	white cullet.
·5	"	manganese.

WHITE GLASS FOR CHEMICAL PURPOSES.

100	pounds	white sand.
41·4	"	potassa.
17·5	"	lime.

Bohemian Glass.—The coarser qualities of this kind of glass are analogous in composition to bottle-glass, and are distinguished by comparative freedom from color, great lightness, and their very refractory nature, which renders them capable of resisting not only high heats, but sudden changes of temperature. Hence the value of this glass for chemical purposes, such as tubing, retorts, *et cetera.* Its lightness, and the almost total absence of coloration—when it is made with pure materials—cause it to be highly valued on the Continent for table-ware, where it is also employed to make costly windows for fine buildings and carriages, for covering engravings, and in general for all those uses which require the glass to have a considerable thickness without coloration. In common with crown-glass, it is also peculiarly fit for optical instruments, in which it is employed to achromatize the flint-glass. These remarks apply to the finer qualities, for which DUMAS gives the following choice of proportions:—

Quartz in powder, or fine silicious sand, washed with hydrochloric acid,....	100	110	120	100
Purified carbonate of potassa,........	60	64	66	75
Very pure carbonate of lime,........	20	24	25	50

In a Bohemian glass of old manufacture, DUMAS found

Silica,....................	69·4	= 36 oxygen.	
Alumina,................	9·6	= 4·48	9·04 oxygen of the bases.
Lime,....................	9·2	= 2·57	
Potassa,................	11·8	= 1·99	

which would give exactly the proportion of 1 : 4 between the oxygen of the bases and that of the acid. On the whole, Bohemian glass may be described as a silicate of potassa and lime, with a small proportion of alumina, magnesia, and other ingredients. This will be obvious from the following analysis of a glass, taken by M. PERDONNET from a manufactory at Neuvelt, and analysed by M. GROS in the laboratory of the School of Mines at Paris:—

Silica,......................	71·6	=	37·1 oxygen.	
Lime, ...	10·0	=	2·81	= 7·83
Potassa, ...	11·0	=	1·86	
Alumina, ...	2·2	=	1·02	
Magnesia,....................	2·3	=	0·89	
Oxide of iron,...............	3·9	=	1·20	
Oxide of manganese, ...	0·2	=	0·05	
	101·2			

Here it will be noted, that the silica contains about five times the aggregate oxygen of the bases. It will be observed also, that in Bohemian glass potassa takes the place of soda.

Tube-drawing.—Though tubes may be formed of any kind of glass, yet, for chemical purposes, and more especially for resisting a high temperature, the Bohemian or German tubes are the best. This may, therefore, be a fitting place to introduce some account of the curious operation of *tube-drawing*, which depends on the singular fact, that when a hollow lump of glass, for instance a globe, is drawn out whilst hot, the cavity in the interior is always preserved, even when the glass is drawn out to the tenuity of the finest thread. The operation is described by KNAPP in the following terms:—

Fig. 149.

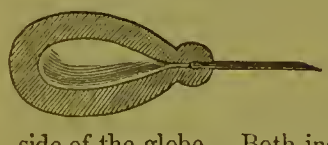
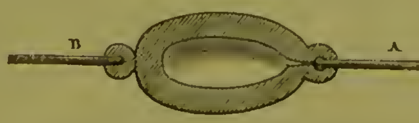


Fig. 150.



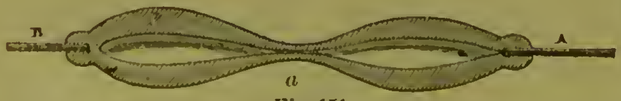
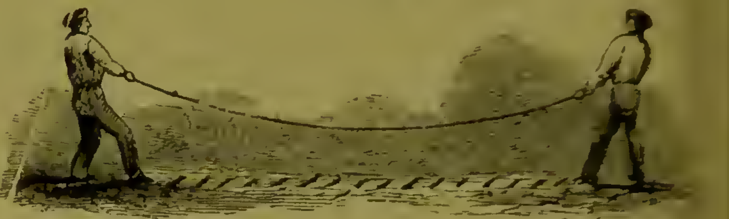


Fig. 151.

Whilst one man collects the necessary quantity of glass on his pipe, and blows this out to a very massive globe, preserving a uniform thickness of the sides as much as possible—Fig. 149—the other attaches a drop of glass to a ponty-rod, and warms it on the fire by the side of the globe. Both instruments are then removed from the fire at once, and the ponty-rod is pushed forcibly against the globe in such a manner as to form exactly a straight line with the pipe, as represented in Fig. 150, where A is the pipe, and B the ponty. This being accomplished, one of the workmen retires backwards as quickly as possible, to the distance of fifty, sixty, or one hundred feet. In this operation the globe at first shrinks, as is represented at *a*, in Fig. 151, and forms the commencement of the tube, which soon cools, and does not diminish in thickness, whilst the mass of glass is spun out by the constant drawing from the warm end. Continual rotation of the pipe and ponty-rod is here as necessary as in all the other operations of glass-blowing, or the part of the tube nearest the ground would cool quickest, and the tube thus assume an irregular form. This, however, does not prevent the tube, in consequence of its great length, from sinking in the middle like a stretched rope and it becomes, consequently, thicker at the two ends, as is represented in Fig. 152. The curve in the tube is, however, remedied by placing it on a ladder before it has become perfectly set; it then straightens, and is cut into lengths of four or six feet each, by taking hold of it with a cold pair of tongs. Tubes cool very uniformly, in consequence of their small amount of metal, and they are, therefore, not placed in the annealing oven. Lastly, the bore of the tube is dependent upon the length to which a given mass of glass is stretched, or, the length being the same, upon the mass of glass: the stoutness of the tube is, however, determined by the thickness of the sides of the original globe, as the relation between the thickness of the sides and the bore is not altered by drawing. Wide, thin tubes—such as are used for spindles, *et cetera*—must therefore be drawn out of a large thin globe, and *vice versâ*: it is necessary, however, whilst the tubes are drawing to blow into them, that the sides may not sink in. —*Knapp.*

Fig. 152.



Foreign Crown-Glass.—The name of crown-glass is limited in this country to that which is formed into circular tables by the process of blowing; but the crown-glass of the Bohemian glass-houses assumes the variety of forms which belong to articles of luxury and art, and is generally moulded into different shapes, with a view to grinding and polishing. Regarded in this light, the foreign crown, properly so called, is rather distinguished by its composition, than by the methods of manipulation adopted in its manufacture. Like the coarser Bohemian glass, it is a silicate of potassa and lime; whereas, in the English crown, soda is employed, either in the shape of sulphate or carbonate. DUMAS analysed a good crown-glass of German manufacture with the following result:—

	Centesimally.		Oxygen.	
Silica,....................................	62·8	=	32·6	
Alumina, oxide of iron and of manganese,	2·6	=	1·2	8·4
Lime, ...	12·5	=	3·5	
Potassa, ...	22·1	=	3·7	

So that in this case the silica contained about four times more oxygen than the bases, and the quantity of oxygen in the lime and potassa, the two principal bases, was nearly the same. As this glass is chiefly manufactured for the same uses as crystal, it is better prepared by means of suitable moulds than by simple blowing, partly because the forms required are frequently so complex as scarcely to admit of their being made by hand, and partly because the various indentations and projections upon the surface can be roughly given by means of a mould, and time and trouble are thus saved in the subsequent laborious operations of grinding.

As the beauty and value of this glass depend upon its absolute limpidness, the most careful selection of materials, both for the mixture and the pots, and a protracted and assiduous process of fining are required. Speaking of foreign crown-glass, Dumas remarks that it is not an easy matter to arrive at a certainty of success in its manufacture. It is evident, he adds, that to obtain it without color, one must use potassa, and not soda. Even if the soda yielded a colorless glass, it should still be put aside on account of the facility with which glass having a soda base devitrifies, which would render the thick masses that require a long cooling quite milky, and full of crystalline and opaque nodules. Crown-glass should therefore be formed with a potassa base, and without oxide of lead; but lime must also be added. By forming a glass with merely a potassa base, there would be no danger of devitrification; but the glass would be soluble in boiling water, and consequently hygrometrical. This would be a serious disadvantage; for spectacle-glasses or other lenses so formed would constantly tarnish by the deposit of a film of aqueous vapor, and in the space of a few years would altogether lose their polish. This inconvenience is avoided by adding to glass with a base of potassa a certain quantity of lime; but then arises a not less serious evil—a proneness to devitrification. Glass with a base of potassa and lime, submitted to the prolonged annealing which thick masses intended for large lenses require, is apt to assume the milky aspect which indicates a commencement of crystallization in the mass. Thus the manufacture of crown-glass, as well as that of flint-glass—the two glasses indispensable for the preparation of achromatic objectives—both present the most serious difficulties, although from very different causes.

III. Window-Glass.—The glass which has long been in common use for window-panes is that which is generally know as *English crown-glass*, in the manufacture of which a large globe is first blown at the end of the pipe, and this is converted by a rapid rotatory motion into a circular plate or disc thickened at the centre. Until a comparatively recent period this was the only method employed in the manufacture of window-glass in this country; but latterly the Continental method has been extensively introduced, which consists in forming the globe into a cylinder, and then, after cutting it up in a direction parallel to the axis, flattening it out into a broad sheet, from which it has received the designation of *British sheet-glass. Plate-glass*, or that which is cast into sheets by pouring the liquid metal on a flat surface, is now beginning to be much used for the same purpose, especially for the windows of shops and fine buildings; but as the chief demand for plate-glass is still for mirrors and other similar articles, this will be treated under a separate head, and in the meantime the term window-glass will be considered as confined to *English crown* and *sheet-glass*, which are composed of precisely the same materials, and differ only in the mechanical operations by which they are brought into form. Chemically speaking, they are the same, except that the nature of the crown-glass manipulation requires a smaller quantity of lime. Plate-glass, on the other hand, is formed with a larger proportion of alkali.

Composition.—The materials employed for the manufacture of English crown and sheet-glass—in other words, of window-glass—are chiefly silica, soda, and lime. This glass differs, therefore, from the foreign crown and Bohemian glass in the circumstance, that soda, as the cheaper alkali, is generally substituted for potassa. Sometimes, however, though rarely, a mixture of the two is employed. Alumina, oxide of iron, and oxide of manganese are also found in window-glass, but only as accidental ingredients. It is true, indeed, that when iron is present, as is almost always the case, the binoxide of manganese is purposely introduced to neutralize its effects; and a little arsenic is generally added to promote the decomposition of the other ingredients.

Mr. Henry Chance, one of the highest authorities on this subject, remarks, that to lay down any standard proportions for window-glass is almost impossible, as no two manufacturers use the same; and even in the same works the melting powers of the furnaces may so far differ as to render necessary, for the production of the same glass, variations in the proportions of its elements. Richardson and Ronalds give the following as the mixtures used in some English manufactories:—

	Pounds.	Pounds.	Hundredweights.
Sand,	560	448	16
Chalk,	154	146	5
Carbonate of soda,	119	168	5
Sulphate of soda,	63	17	1·25
Arsenic,	2	2	0
Cullet,	448	448	16

The introduction of carbonate of soda, prepared from salt, into the glass manufacture of England, dates from the year 1831. Previously to this, kelp was employed as the source of alkali. In the meantime, the French manufacturers—released, in 1825, through the exertions of M. Clement Desormes, from the absurd veto which the government had pronounced on the sale of sulphate of soda—were enabled to turn their attention to the employment of this salt instead of the carbonate. They proceeded with caution in the introduction of the new ingredient—first mixing a small quantity of sulphate with a large proportion of carbonate; then half of each; and, finally, excluding carbonate, they adopted the sole use of sulphate, to the injury, doubtless, of the color of their glass, but gainers by the employment of a cheaper and more manageable material. Where absence of color, however, is an object, as in the manufacture of plate-glass, the exclusive use of carbonate of soda is still retained.

Proceeding cautiously in the steps of their foreign brethren, says Mr. Chance, the English glass-makers, after they had established the use of carbonate, made trial of the effect of a small quantity of sulphate of soda in a large quantity of carbonate. The carbonate gradually decreased, until at length, in the preparation of blown window-glass, sulphate generally stood alone. But here, as abroad, the manufacturers of plate-glass still adhere to the carbonate. The preceding table of three different proportions for crown-glass evidently refers to a period when the carbonate still preponderated in this manufacture also. As the use, whether of carbonate or sulphate of soda, involves their preparation from common salt and sulphuric acid, attempts have been made to accomplish the direct union of silica and salt in the manufacture of window-glass, but have hitherto failed of success. The black bottles of Newcastle are made from common rock salt and sand from the bed of the river, with the carbonate of lime of the soap-works, and the tank waste of the alkali-makers; but for all better kinds of glass the circuitous combination of silica and alkali is still found necessary.

The following is a French composition, which gives, according to DUMAS, a window-glass of fine quality:—

	Parts.	
Sand,	100	
Chalk,	35 to 40	
Dry carbonate of soda,	28 to 35	
Broken glass,	60 to 180	
Binoxide of manganese,	0·25	Sometimes in larger quantity.
Arsenic,	0·20	

The oxygen of the bases in this glass is generally to the oxygen of the acid as one to four.

M. BASTENAIRE gives the three following compositions, which DUMAS considers too rich in alkali, and too poor in lime:—

I.

	Parts.
White sand,	100
Good potassa,	65
Lime slaked in the air,	6
Fragments of white glass,	50
Arsenious acid,	1
Oxide of manganese,	0·30

II.

	Parts.
Very white sand,	100
Good soda,	90
Red oxide of lead or minium,	5
Broken white glass,	100
Carbonate of lime,	5
Oxide of manganese,	0·40

III.

	Parts.
White sand,	100
Good soda,	80
Carbonate of lime,	8
Broken glass,	110
Oxide of manganese,	0·20
Oxide of cobalt,	0·10

In none of these French receipts is the sulphate introduced, and therefore they may be referred to a period anterior to 1825, when, as already remarked, the sulphate began to be generally adopted in the French glass-works. DUMAS remarks that the object to be kept in view in employing this salt, is to render its decomposition by the silica as quick and easy as possible; and he adds, that this is managed by adding to the mixture a suitable quantity of charcoal, to transform the sulphuric acid into carbonic and sulphurous acids. Thus—

$$\underbrace{2\ S\ O_3}_{\text{Sulphuric acid.}} + \underbrace{1\ C}_{\text{Charcoal.}} = \underbrace{2\ S\ O_2}_{\text{Sulphurous acid.}} + \underbrace{C\ O_2}_{\text{Carbonic acid}}$$

For each equivalent of dry sulphate of soda there is required, therefore, one equivalent of charcoal, or else about six of charcoal for seventy-two of sulphate of soda. But to avoid coloring the glass yellow, only five equivalents of charcoal are employed. Thus, to produce a beautiful window-glass, continues the same writer, the following proportions are taken:—

	Parts.		Parts.
Sand,	100	....	100
Dry sulphate of soda,	44	....	58 to 75
Charcoal in powder,	4	....	4·5 to 5·5
Slaked lime,	6	....	13 to 15
Broken glass,	from 20 to 100	....	25 to 100

Mechanical Operations.—It has been stated that the difference between English crown and cylinder or sheet glass, is almost entirely in the manipulation. The above materials and proportions apply to both, inasmuch as the two are the same window-glass in the pot. The specific description of these two varieties, if they may be so distinguished, involves, therefore, only a series of mechanical operations, which do not strictly belong to the special object of this work. Yet, as the present article would be incomplete without such details, the Editor will here introduce a short account of both processes, beginning with crown-glass as the oldest; and, in doing so, he begs to acknowledge his obligations to Mr. HENRY CHANCE, by whose kindness he is permitted to present the reader with the following animated account of the mechanical part of the manufacture, from a paper which was read by that gentleman before the Society of Arts, in January, 1856.

1. *English Crown-Glass.*—Assuming one or other of the mixtures or compositions above given to be melted in the crown-glass pot, represented in Fig. 141. Mr. CHANCE begins by observing, that upon the surface of the melted glass is a ring of fire-clay, which, when the materials were thrown in, lay at the bottom of the pot, and after the completion of the melting, found its way upwards. This ring is of great service, for, floating in the centre of the pot, it prevents the exterior surface of the metal, or melted glass, which becomes stiff and stringy during the long period of working, from mingling with the interior or hotter surface, which thus remains throughout of a suitable consistency. The labor, also, of the skimmer, whose duty it is to clear the surface of the metal from any scum or dirt that may collect upon it, is considerably diminished by the ring, which, limiting the space from which the glass is drawn, limits also the space which it is necessary to cleanse, and any bubbles or impurities in the glass have a tendency to attach themselves to the ring.

The metal, or melted glass, having been brought, by the gradual cooling of the furnace, from a state of complete fluidity to a consistence capable of being worked, the *gatherer* dips the end of his pipe, or hollow rod of iron, into the pot inside the ring, and twirling it round its axis, to equalise the thickness of the gathering, collects upon the end, or nose, as it is technically called, a pear-shaped lump of glass, similar to that represented at A, Fig. 153. Resting his pipe upon a stand or horse, he turns it gently round, and allows the surface of the lump to cool, to fit it for a second gathering. So much glass is collected in this way, in successive layers, as will form a disc or table of about nine pounds weight, and an experienced workman seldom fails more than an ounce or two in the correct weight. The lump completed, the gatherer, having cooled his pipe under a trough of water, that he may handle it at any point, proceeds to roll the glass upon the marver, or metallic bed, until it assumes a conical form, the apex of the cone forming what is termed the *bullion-point*. A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small globe. Having been heated, it is blown again, and assumes the shape of a Florence flask, as shown at B, and the future rim of the developed plate or disc is prepared by rolling the *piece*, as the glass under operation is technically termed, near the pipe nose, upon the edge of a marver. Again heated, it is now expanded by the blower into a large globe. During this expansion, it is important to keep the bullion-point exactly in the position which it previously occupied, in a line with the axis of the pipe. To effect this, the blower rests his pipe upon an iron support, and while he blows down the pipe and turns it round at the same time, a boy holds against the bullion-point a piece of iron terminating in a small cup. This operation is represented in Fig. 154. Again presented to the fire, by the peculiar manipulation of the workman, and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution round its axis. The piece now resembles somewhat in shape an enormous decanter, with a very flat bottom and a very short neck, as at C, Fig. 153. The bullion-point is still to be seen in the centre of the flat bottom, and its use now becomes manifest. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand the large rod of iron called the ponty, tipped with a lump of molten glass. Pressing this lump upon an iron point, so as to give it the form of a little cup, he fits it, when thus shaped, on to the bullion-point, to which it soon becomes firmly attached. The lump thus formed is called the *bull's-eye*, or bullion of the developed plate. The incision of a piece of cold iron in the glass round the nose of the pipe, and a smart blow, soon detaches the pipe, leaving a corresponding hole in the flattened sphere, at a point exactly opposite the attachment of the ponty, as shown at D in Fig. 153. The blowing pipe thus removed, and carrying with it a piece of glass, is allowed to lie idle a few minutes, till the glass adhering to it has cracked off; it is then warmed, and carried back to the pot to repeat its course in a similar operation.

Fig. 153.

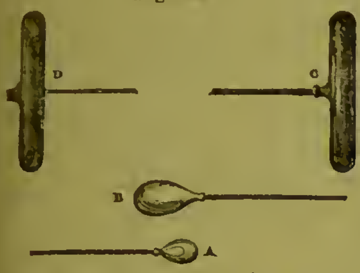
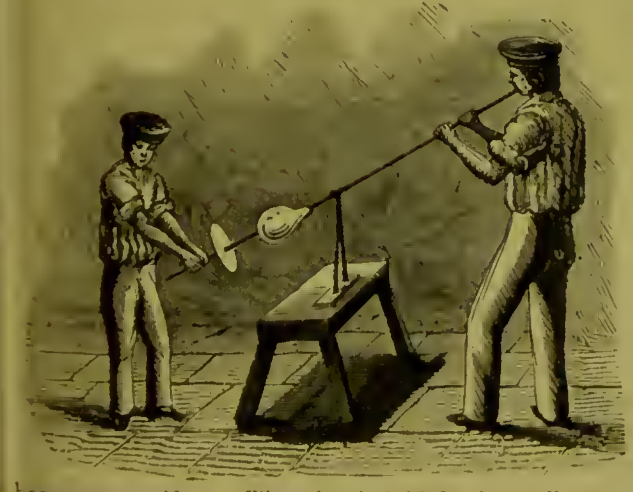
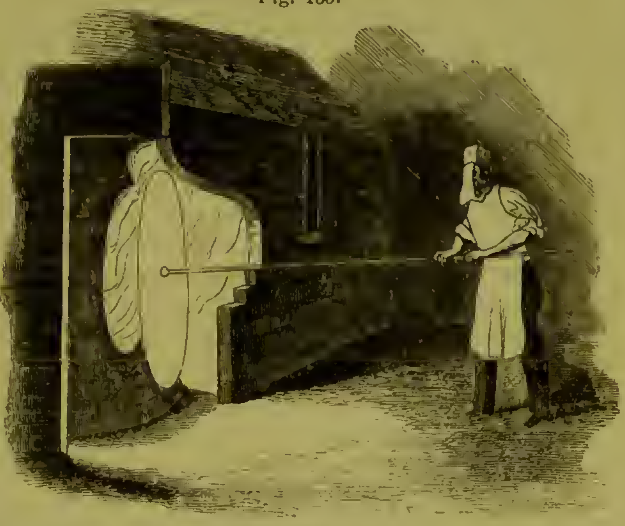


Fig. 154.



The open projecting end of the piece, which was next the now detached pipe, is called the nose, and gives its name to the furnace or nose-hole, where this nose is, on account of its thickness, heated almost to melting, with a view to the next operation. It is now that the glass undergoes its last and most dreadful torture in the hands of a man who, with a veil before his face, as shown in Fig. 155, stands in front of a huge circle of flame, termed the *flashing furnace*, into which he thrusts his piece, rapidly, meanwhile, revolving his ponty. The action of heat and centrifugal force combined is soon visible. The nose of the piece, or hole caused by the removal of the blowing pipe, enlarges, the parts around cannot resist the tendency, the opening grows larger and larger; for a moment is caught a glimpse of a circle with a double rim; the next moment, before the eyes of the astonished spectator, is whirling a thin transparent circular plate of glass, which, but a few minutes before, was lying in the glass-pot, an indistinguishable portion of the molten mass. The sound of the final opening of the piece has been compared to that produced by quickly expanding a wet umbrella. In this way a flat circular disc, nearly sixty inches in diameter, or sometimes more, is produced, of almost uniform thickness, except at the point of attachment to the ponty, where there is a swelling called, as already stated, the bull's-eye. The glass at the edge of the disc is also in some cases a little thickened. Still whirling, the *table*, as it is now called, is carried off, laid flat upon a support called a whimsey, detached by shears, or otherwise, from the ponty, lifted into the annealing kiln upon a fork, E—Fig. 146—and piled upon its edge against the preceding table. The weight of so many tables pressing one against another, would cause the hindermost to bend; but this is prevented by the intervention of iron frames, or dros-

Fig. 155.



sers, which divide the tables into sets, the first drosser leaning against the wall of the kiln, the second against the first, and so on; and thus rendering each set of tables independent of those behind it for support. As the bull's-eye, or centre lump, which the ponty has left behind it, keeps each table from close contact with its neighbors, the air passes freely between them, and the annealing is completed with tolerable rapidity, varying from twenty-four to forty-eight hours, according to the number of tables in the kiln. From the kiln the tables are conveyed to the warehouse, having passed, since their first exit from the pot, through the hands of ten distinct workmen.

Such, with a few slight additions and illustrations, is the description of this most interesting process given by Mr. Henry Chance. He adds that the process may be regarded as twofold—first, the development of the lump into a sphere; and, secondly, the resolution of a sphere into a circular table. Constant rotation of the glass, while in a yielding state, is an essential element of this process; as, if allowed to remain motionless, its symmetry would be immediately destroyed.

A table of crown glass of to-day, would scarcely recognise as of kindred origin a table of the earlier part of the present century. The principle of the process in each case was the same; it is the improvement of minute details that produces so different a result. To Mr. Hartley and Mr. Chance, who, during the years 1832 to 1836, gave to the manufacture of this glass their constant attention, is owing, in a great measure, its present status.

When the tables of crown-glass are drawn from the kiln, they are covered with a whitish film or *hum*. The history of this hum, continues Mr. Chance, is curious. It arose, probably, in the first instance, from the deposition of sulphur from the fuel upon the surface of the glass. It thus became associated with the process of annealing, and buyers fancied that the more hum there was upon the glass, the better was the glass annealed. The manufacturers of crown-glass, ever ready to accommodate themselves to the fancies of their customers, have taken the trouble to produce an additional hum by the introduction of sulphur in the kiln. The members, however, of the Glass Jury of the Paris Exhibition, not being in the secret of this hum, stoutly maintained that glass thus clouded must be bad glass, and that the hum was owing to the exudation of the alkali.

In the warehouse, the tables are laid upon a *nest*, or cushion, and are divided by the diamond of the splitter into two unequal parts—the larger half containing the bull's-eye. The diameter of the table is measured on the nest, the usual size being now about fifty-four inches, and weighing thirteen pounds. Tables have been made as wide as seventy inches, but the difficulty of manipulation, and the uncertainty of the result, render such sizes too costly to be general.

The splitter carefully examines each table before splitting it, and turns it round till he has brought it into the position in which he may split it to the best advantage, announcing at the same time its quality. The first quality is called *best*—the next, seconds—then thirds—fourths—CC—CCC or Irish—and tables containing any very glaring defects, come under the denomination of *course*.

These variations in quality depend on the presence or absence, number and extent, of those defects to which, even in the best regulated manufactories, glass is unavoidably liable. Perhaps the glass has been badly melted, and is seedy—that is, full of little vesicles, to which the rotary motion has given a circular shape. Or the gatherer may have enclosed air within his *metal*, and a gatherer's blister is the result; or a pipe blister, or pipe-scales, or dust from the pipe-nose, or dust from the marver, or dust from the bottoming-hole, or dust from the nose-hole, or dust from the flashing-furnace, or bad bullions, or scratches, or music lines, may disfigure the table, or the glass may be crizzled, or curved, or bent, or hard, or smoky, or small and light, defects to explain which would be a long and dreary task. No wonder that tables of the best quality are few and far between, in some manufactories a forlorn hope never to be realized.

The difficulty of obtaining glass free from defects will account for what may at first astonish—the fact that the value of a table of the highest quality is three times that of the lowest.

The defects enumerated, many as they are, are instantly detected, even through the obscuring hum, by the splitter, who not only can descry faults invisible to ordinary eyes, but can refer each fault to a particular stage of the process, and to a particular cause in that particular stage, and the faults are registered accordingly. The nomenclature of defects is much facilitated by the mapping out of the table into certain ideal divisions, derived from shapes assumed during various periods of the process. The centre lump is termed the bullion, round this lies the bottom; next the bulge; the shoulder; the top, and the rim, or the outermost edge of the circle.

Independently, however, of these defects, there are certain other disadvantages under which even a faultless table of crown-glass must unavoidably labor. The cutting of a circle into rectangular sheets, must necessarily be attended with waste, while the bull's-eye confines those sheets to comparatively small sizes. Uniformity of thickness, also, except by the most skilful manipulation, is difficult of attainment. Wavy lines, termed music lines, forming a series of concentric circles round the bull's-eye, and owing to the treatment of the glass upon the marver, were formerly a common defect; but improvements in the process have in a great measure removed them.

On the other hand, extreme brilliancy of surface is a distinguishing characteristic of this glass, ascribed by some to the influence of the marver, by others to the effect of the flashing-furnace.

It is this brilliancy of surface which has enabled crown-glass to maintain in England its position against that formidable rival which is now to be briefly described.

Cylinder, or Sheet-Glass.—The above method of making window-glass has long been abandoned on the Continent, where the glass is first formed into a spheroid, the ends of which are cut off, so as to form a cylinder open at both extremities; this is then cut lengthwise with shears, or a straight line is traced with a drop of water in the direction of the length of the cylinder, and over the line so traced a red-hot iron is passed, which immediately produces a very uniform crack or fracture along the whole length. The cylinder, thus split up, is then taken to the furnace to be spread or flattened out into a sheet. The glass so manufactured, though formed of the same materials as crown-glass, is coarser in texture, more wavy and dull, but allows of larger sheets being formed, since crown-glass can only be cut up into comparatively small panes, in consequence of its circular form and the central bull's eye.

M. **Bontemps** remarks that there is no evidence by which to determine the relative antiquity of the crown and cylinder glass processes. There is reason to believe, however, that even in this country the latter was the more ancient, although at a comparatively early period it was abandoned in favor of the rotary method. The cylindrical process is the only one mentioned by **Theophilus** in the thirteenth century; and this method was adopted by the Venetians, as the more uniform thickness which resulted from it insured, in their colored glasses, a greater uniformity of tint. But in France, England, and the North of Germany, the cylindrical process fell gradually into disuse, as the demand for colored glass diminished, and at length in these countries the rotary principle exclusively prevailed. Bohemia, however, still retained the cylindrical method, which she had learned from Venice, and this method was reintroduced into France by M. **Drolenvaux** in 1730 with great success. Hence speedily resulted, not only in France, but also in Belgium and the North of Holland, where the style of building required panes of large size, the general abandonment of the rotary principle, and the adoption of the cylindrical, which continues, as already stated, to be practised universally on the Continent at the present day.

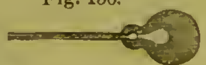
In England the manufacture of crown-glass maintained its position, notwithstanding its abandonment abroad, and attained to such superiority over the spread or broad glass manufactured on the German principle, that the former was used for all houses of the better class, while the latter was confined to poorer dwellings. The inferiority of this spread glass, manufactured indeed on the German principle, but by no means so good as the German glass, tended to prejudice the public against all glass made by the cylindrical method. This prejudice was, however, gradually overcome, by the establishment in England of the manufacture of cylindrical glass, according to a process introduced from France, and from which resulted a glass that has entirely displaced the manufacture of spread glass. The latter was so called from the circumstance that the cylinder, unskilfully blown, and then cut open with shears, as already stated, was spread out immediately upon a plate of iron covered with sand. Hence not only was the thickness of this glass very irregular, but its surface very coarse.

The introduction into this country of the manufacture of cylindrical glass by the French method, was due to the Messrs. **Chance** of West Bromwich, near Birmingham, and Mr. **Hartley**, now of Sunderland, but then in partnership with the Messrs. **Chance**, who, on visiting in 1830 the works of M. **Bontemps**, near Paris, were much struck with the advantages of the glass made on this principle, and having secured the co-operation of M. **Bontemps**, commenced the process at their own works in the autumn of 1832. So great, however, were the difficulties to be overcome, that it was not till 1838 that the fabrication of this glass was completely established. Since that time there has been great progress, and the sheet-glass now manufactured in this country, though inferior in color, is in other points generally superior to that of the foreign teachers. On this point Mr. **Bannatyne**, in the new edition of the *Encyclopædia Britannica*, says:—The French, Belgians, and Germans, having pursued the cylindrical system for the last fifty years in making their window-glass, have much improved the old method of making it; and as the parties who are now manufacturing this article in England—namely, the Messrs. **Chance** and Mr. **Hartley**—are crown-glass makers, and have imported all the improvements adopted in the making of sheet-glass in France, Belgium, and Germany, and combined with these the improvements which their experience as crown-glass makers had taught them during the same period, they have surpassed the French, Belgians, and Germans in sheet-glass, and can now compete with them in all parts of the world.

After this testimony, the following account of the process for making British sheet-glass, as given by Mr. **Henry Chance**, one of the partners of the eminent firm above-named, will be received by the reader as of very high authority:—

Imagine, as before, a lump of glass collected upon the end of the gatherer's pipe. For the metallic table or marver is now substituted a block of wood, so hollowed out as to allow the lump, when placed upon it, to be expanded by the blower to the diameter ultimately required. The block, during this operation, is sprinkled with water, to prevent the wood from being burnt, and from scratching the glass. In the meantime the lump is slightly distended by blowing, and, having received the shape represented in Fig. 156, it is carried from the block to the blowing furnace, which is accessible through a number of holes or openings, each hole being allotted to a single blower. In front of the furnace, corresponding to each opening, is a stage or frame of wood, erected over a large pit or well about ten feet deep—as represented in Fig. 157—and these parallel stages are sufficiently apart to enable each blower to swing his pipe to and fro in a vertical plane, that the glass may run freely out, as the phrase is, to the required length. When the glass has been sufficiently heated in the blowing furnace, it is brought out, and held over the head while blown, until it assumes by its own weight the flattened form represented in Fig. 158. It is then swung round in a vertical plane, as well as backwards and forwards, and the blower at the same time, by blowing down the pipe, constantly keeps the lengthening cylinder full of

Fig. 156.



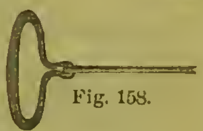


Fig. 158.

air. The first form which the glass assumes in consequence of the swinging motion is represented in Fig. 159. If the man were to blow without swinging, a globe or sphere would be formed, as indicated by the dotted line. Uniformity of substance and of diameter is chiefly secured by the skill of the workman, who, when he finds the metal running out too freely, repeats the operation of holding the cylinder vertically above his head, still keeping it well filled with air. These operations are continued until the cylinder has reached the length required, as in Fig. 160.

Fig. 157.

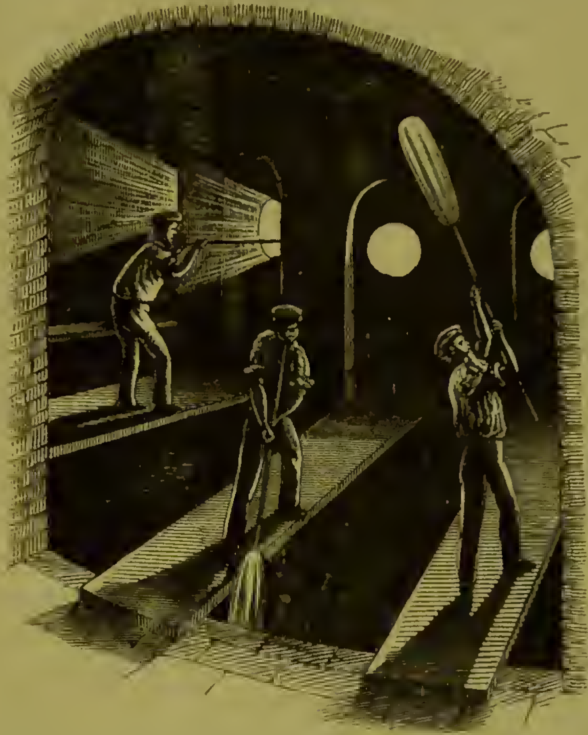


Fig. 162.

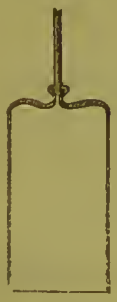


Fig. 161.

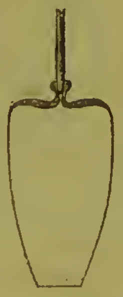


Fig. 160.

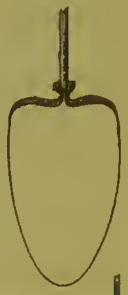
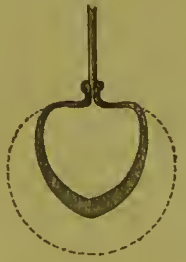


Fig. 159.



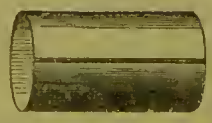


Fig. 164.

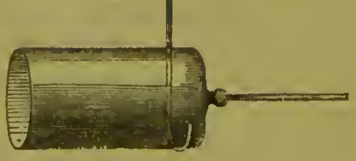


Fig. 163.

The next stage of the process is opening the end of the cylinder. The thinner kinds of glass are all opened by submitting this part to the fire, and at the same time forcing in air through the pipe, and stopping up its aperture with the thumb. The air is expanded by the heat of the fire, and bursts open the cylinder at the end, this being the hottest and most yielding part. The thick and uneven margin of the aperture thus formed is trimmed with scissors, and the cylinder now appears as in Fig. 161. The aperture is then widened out to the full diameter of the cylinder with the pucellas, and by turning the cylinder to and fro with the opening downwards, until by the centrifugal force, and its own gravity, the yielding glass assumes a uniform diameter with parallel sides, as shown in Fig. 162.

The ends of the thicker cylinders, if these were opened in the furnace in the manner above described, would be so thinned out that a considerable portion would be wasted. An extra mass of hot glass is therefore incorporated with such cylinders at the end, which thus becomes the hottest and weakest part, without applying them to the furnace, and the air forced in as before bursts them open. The opening is then enlarged by cutting round it with scissors.

The neck or cap is now removed by supporting the cylinder on a chevalet or wooden rest, and turning the upper part two or three times in the curve of a bent iron heated to redness, as shown in Fig. 163; a drop of water allowed to fall on the heated line produces fracture and separation of the cap. Or, the same may be done by wrapping round the end of the cylinder a thread of hot glass, removing the thread, and applying a piece of cold iron to any part which the thread covered.

The cylinder, as it now lies upon the chevalet, is little more in weight than two-thirds of the lump of glass which the gatherer collected on his pipe. The quantity left upon the pipe-nose, with that which formed the cap of the cylinder, are nearly equivalent in weight to one half the cylinder.

The next operation is to split it open along its length in the manner represented in Fig. 164. Till of late this was uniformly done by means of red-hot iron and water —a method which is still practised on the Continent: but in the English glass-works, it is now effected with greater certainty and regularity by a diamond, which, attached to a long handle, and guided by a wooden rule, is drawn along the inside length of the cylinder. In performing this operation, it is important to make the line pass through, or in the neighborhood of, some notable defect or group of defects, if such be present, for the line forms two edges of the future plate, and defects brought to the edges are of lessened injury to its value. An object to be avoided is the black mark which the cylinder sometimes receives from the charring of the wooden chevalet, on which, while hot, it rested in the glass-house. If the diamond passes, inside the cylinder, over the space occupied by this mark on the outside, the cylinder will fly to pieces. The reason of this, says Mr. Chance, is not difficult to understand. The chevalet prevented, by its non-conducting tendency, that portion of the glass with which it was in contact, from cooling equally with the rest, and the particles at that point remained in a state of tension. A careful blower will never place any large defect in his cylinder in contact with the chevalet, being aware of the probable result.

The use of the diamond in dividing plain surfaces of glass, dates from the sixteenth century; but its application to the splitting of cylinders which had not undergone the process of annealing, was introduced only about twenty years ago by M. Claudet, the distinguished photographer, then a glass manufacturer. Previously, all such cylinders were split by a red-hot iron, and, even now, all cylinders of flashed glass, that is, of ordinary sheet-glass covered inside with a skin of colored, are still split in the same fashion. On the Continent the diamond is gradually replacing the use of red-hot iron, though the latter is still the method more generally practised.

Having been split along its length, the cylinder is now ready for the flattener, who, having prepared it by a preliminary warming in the flue by which it is introduced into the *flattening-furnace*, passes it, by means of a croppie, or iron instrument bent at right angles, on to the *flatting-stone* or *spreading-plate*, which ought, of course, to be perfectly even and smooth, as the soft glass moulds itself to the surface upon which it is flattened by heat. The sandstone of Godstone, in Surrey, has been found to answer well for this plate, which, however, is usually covered with a *lagre* or sheet of glass. Upon this lagre, B B—Fig. 165—the cylinder, lying with the split uppermost, is soon opened by the flame passing over it, and falls back into a wavy sheet. The effect of the heat is assisted by spreading out the softened sheet, A, with an iron ruler, C, introduced through an aperture in the furnace. The flattener now applies another instrument, a polissoir, or rod of iron, C, Fig. 166, furnished at the end with a block of wood, D, and rubs down the waviness into a flat surface, often, upon a refractory piece, using considerable force. Some cylinders are so distorted in the blowing that no rubbing can flatten them; but all, good, bad, and indifferent, pass through the same treatment. The flattening stone is now moved on wheels to a cooler portion of the furnace, and by the aid of the flattening fork, delivers its sheet to another stone, called the cooling stone. From this, when sufficiently stiff, it is again lifted, and then piled generally on its edge, in order to be annealed.

Fig. 165.

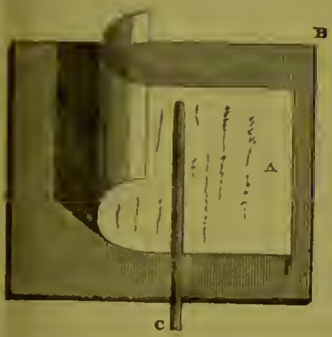
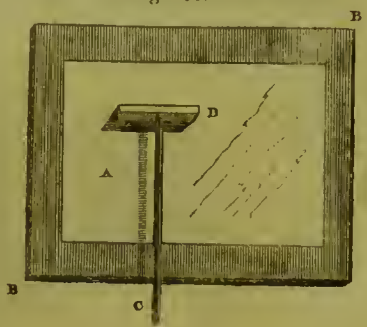
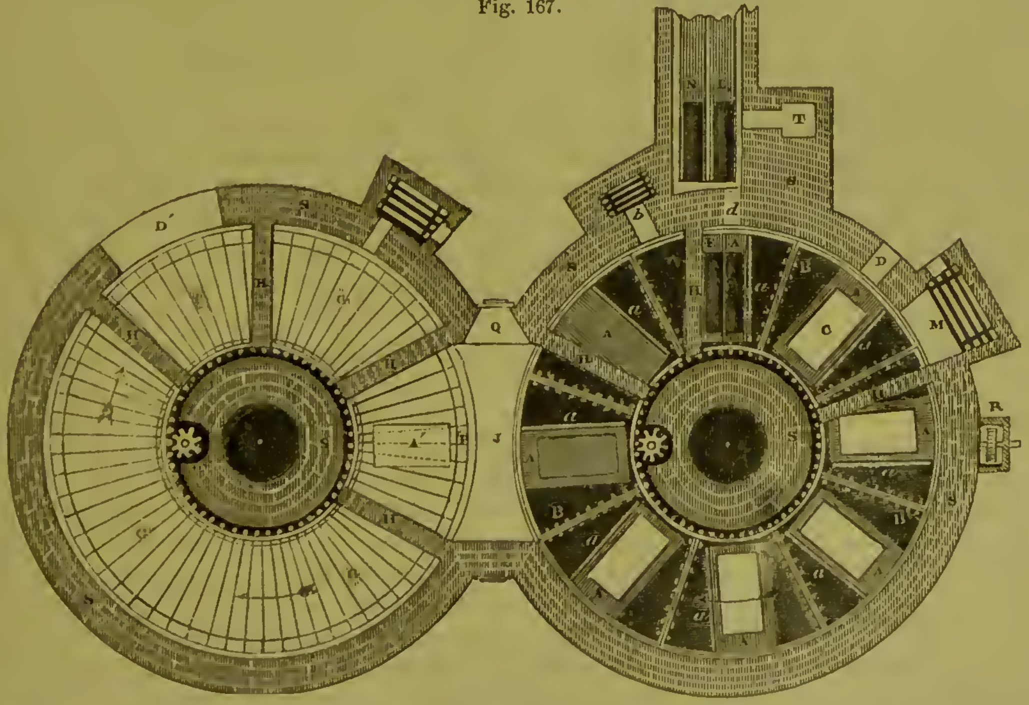


Fig. 166.



In 1842 the Messrs. Chance patented certain improvements, whereby, instead of at once removing the glass from the flatting to the annealing furnace, and lifting it to the cooling-bed while soft and liable to distortion, they flat and cool it by passing it through a succession of decreasing temperatures, so that it is not lifted until it becomes quite stiff and rigid. By this arrangement the workman can flatten the glass while the annealing is in progress, which could not be effected by the old method, because the temperature of the flattening kiln must be reduced with that of the annealing kiln, to which it is contiguous, thus leading to the successive heating and cooling of the kiln, and waste both of time and fuel. At Messrs. Chance's establishment the flatting and annealing kilns are two circular buildings communicating with each other, and shown in plan and elevation in Figs. 167 and 168. Each of the buildings consists of exterior and interior walls, S, the intervening space being a circular arched vault. In each vault is a cast-iron frame, moving on casters, and capable of being turned round by a winch on the outside, communicating with the shaft and bevil wheels, R R—Fig. 168. The frame, B B, in the flatting kiln carries the flatting stones, *a*, and lagres, A, eight in number, and that in the annealing kiln a number of metallic wires, G, radiating towards the centre of the building, for supporting the sheets of glass. The flatting kiln is heated by the grate, M, and in order that the stones and

Fig. 167.



lagres, which will have cooled during the rotation, may be re-heated and arrive at the position, F, at a proper temperature, a second smaller grate is placed at *b*. If coke be used, a chimney at T will be required, but with wood fuel it will not be needed. Partitions, H, are placed at certain intervals, to prevent the too rapid dissipation of the heat from those parts where it is most required, and to retard the entrance of cold air through the openings in the external wall. At the bottom of the partitions are spaces to allow the frame, with the stones and glass or the wires and glass to pass below. The space, J, on which the glass is shifted from the lagres to the wires, is lighted by gas. The kiln is worked in the following manner:—The cylinder of glass is first placed in the position, N; then in that of L; thirdly, it is introduced through the external wall, *d*, and placed on a stone, E, suspended over the lagres; it is lastly placed in the position F, on the lagre beneath. To prevent the cylinder rolling off, the stones are provided with a ledge. This part of the kiln is shown separately in Fig. 169. The frame B is then turned round till the cylinder of glass occupies the position C, opposite the working hole, D, through which it is then flattened in the ordinary way. From C the glass passes round in the direction shown by the arrow, till it arrives opposite J, when it is shifted to the position A′ on the wires, by the flattener using his instrument through the opening, Q; and after passing through the successive positions, arrives finally opposite D′, where it is drawn out fully annealed. Thus each sheet of glass, after having been flattened, remains on the stone during the time that other cylinders are being flattened, and before the sheet is lifted off the stone, it has passed through a gradually decreasing temperature, and has become rigid. The annealing is also carried on without lowering the temperature of the kilns by the movement of the frame, and the sheets, being isolated by the wires, become more quickly annealed.

Fig 168.

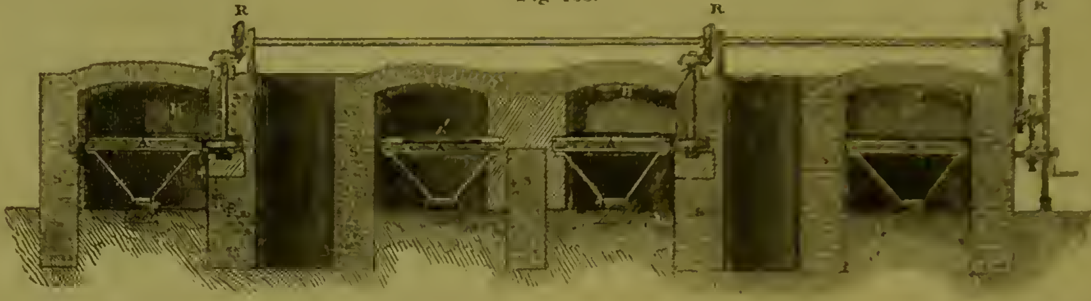
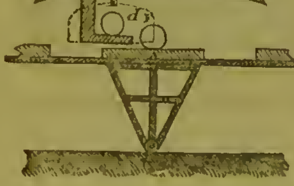


Fig. 169.



Mr. Hartley, of Sunderland, introduced two improvements in this operation. One consists in making part of the floor of the flatting kiln to consist of a movable stone, about ten inches in diameter, on which the cylinder is placed, and by causing the stone to revolve on its axis, the cylinder is gradually exposed on all sides to the action of the fire, thereby avoiding the objection to the previous plan, where one side of each cylinder became so much hotter than the other. His other improvement consists in making holes, about the eighth of an inch in diameter, all over the flatting-stone. When the sheets of glass are to be polished, the absolute smoothness of the original surface is not so much an object as to have them perfectly flat, and the air which lies between the common flatting-stone and the cylinder or spread sheet renders this difficult to accomplish; but by Mr. Hartley's process the difficulty is overcome.

One of the most recent improvements is that of Mr. Farthing, in which the kiln is heated by means of flues arranged under the floor, around the walls, and over the arch. By this means all deposit of dust or hard particles from the fuel on the surface of the glass is avoided, and any cheap kind of fuel may be employed.

To return to the flattened sheets. When annealed, they are drawn from the kiln, and carried to the warehouse, where they undergo examination. Being blown by a less complex process than crown, sheet-glass is liable, in the glass-house, to a less number of defects, but the subsequent process of flattening, notwithstanding the improvements above mentioned, often makes up the deficiency; and the manner in which a sheet, spared by one process, is disfigured by another, is described by Mr. Chance as sometimes curiously provoking. Standing upon the table of the *assorter*, he remarks, your eye lights upon a piece which, blown under an evil star, has imbibed in the glass-house every possible defect. The founder, skimmer, gatherer, and blower have all stamped their brand upon it. It is seedy—the vesicles, which were in the crown tables rounded by the rotary motion of the piece, are here elongated by the extension of the cylinder; it is stony, disfigured with stony droppings from the furnace; stringy, thin threads of glass meandering over its surface; *ambitty*, covered with stony speckles, symptoms of incipient devitrification; conspicuous with gatherers' blisters and blisters from the pipe—badly gathered; badly blown—thin here, thick there, and grooved with a row of scratches: and on this abortion the flattener chances to have exerted his most exquisite skill; it has passed through his hands unscathed, flat as a polished mirror, yet, from its previous defects, is entirely worthless. Next comes before you a piece whose beginning was miraculous—no seed, no blisters; it prospered under the hands of the gatherer and blower, and left the glass-house a perfect cylinder. But the croppie of the flattener marked it: the fire scalded it; dust fell upon the lagre and dirtied it; scraps from the edges of the preceding cylinder stayed upon the lagre, and stuck to it; the stone scratched it; and the heat of the annealing chamber bent it. Such are the difficulties to which every cylinder is subject—those of the glass-house, and those of the flattening kiln. Not all, however, are such as these; there are good as well as bad, but the good are generally in the minority

The qualities range thus—best, seconds, thirds, fourths, and H, the latter standing for horticultural, and including all coarse glass, such as may be applied to horticultural purposes. The difficulty of escape from defects renders the best quality, as in crown-glass, three times as costly as the common. The expense of production to the manufacturer is in each case the same; the materials, the labor, the fuel, the same for each. Success, therefore, clearly hinges on the proportion of good glass which a manufacturer can obtain. The six qualities of sheet-glass may each consist of six different thicknesses, forming thus, in all, thirty-six varieties.

When this manufacture was new in England, the size usually blown was thirty-six inches long, and twenty wide. The usual size now is forty-seven inches long by thirty-two wide, and cylinders are occasionally blown seventy-seven inches long; but large sizes and heavy weights are accomplished only by workmen of the first class. A sheet of this latter size, containing twenty-one ounces to the foot, would require for its formation a lump of glass upon the gatherer's pipe, of no less than thirty-eight pounds weight.

The size which sheet-glass can thus reach is obviously a great advantage, and adapts it to many purposes from which the limited dimensions of crown are excluded. It was this glass that covered the Great Exhibition in 1851. A cylinder was blown to cut, as the phrase is, forty-nine inches by thirty; this was subdivided into three panes of forty-nine inches by ten. About three hundred thousand of these, extending over a million square feet, and weighing upwards of four hundred tons, were the work of a few weeks, and this without absorbing or interrupting the ordinary produce of the manufacturer. The energy of the glaziers was equal to their task; eighteen thousand three hundred and ninety-two panes were fixed in the roof in one week by eighty men, one hundred and eight panes being accomplished by one man in a single day. It was the house of CHANCE and Company which executed the large order for the Exhibition, without materially affecting their power of executing their general orders, a feat almost unparalleled in the history of the manufactures of this country.

But sheet-glass has its faults as well as its virtues; it is devoid of that brilliancy of surface for which crown is so remarkable. It is subject, also, to undulations on the surface, the precise origin of which it is difficult to explain. Mr. SHAW, in his admirable lecture on the glass manufacture, as illustrated by the Great Exhibition, speaking of this defect, says—When the divided cylinder is softened by heat, and either allowed to flatten by its own weight, or flattened by the workman, the concave interior of the cylinder has to expand, and the convex exterior to contract, as the curved surface becomes plane. He adds, were this contraction and expansion to take place uniformly throughout the glass, the undulation in question would not occur, but since one part invariably yields somewhat more readily than another, perfect flatness cannot be attained.

It is, however, more probable, in Mr. H. CHANCE's opinion, that this undulation is produced in the operation of blowing, and is due to the double movement of the particles of glass which accompanies the formation of every cylinder, the one movement being parallel to the axis of the cylinder, and the other in planes at right angles to that axis.

Grinding and Polishing Sheet-Glass.—A further development of the sheet-glass manufacture in England is the process of polishing and grinding this glass by machinery, whereby a new branch of manufacture has been established, which has furnished glass peculiarly applicable for purposes for which none previously existed. This improvement, which is the work of Mr. JAMES CHANCE, is characterized by M. CLAUDET as one of the greatest improvements which has ever been introduced in the manufacture of window-glass, as it has produced, at a cheap price, an article equal in effect to plate-glass, and by which houses can now be glazed with a glass that does not distort external objects, while, at the same time, when viewed from the outside, it has all the polish and fine appearance of plate-glass. To explain the merits of this invention, it must be recollected that the sheet-glass has the polish of its surface much injured by the mode of its production, and that a still greater defect arises from the inside and outside of the cylinder not being of the same length, so that when developed by the flattening operation either the one surface must contract or the other expand; and the result is a kind of undulating or wavy appearance called *cockles.* These cockles reflect and refract light in various directions, and the objects seen through the glass are necessarily distorted.

Several attempts, continues M. CLAUDET, were made in France and Germany to grind and polish this glass, in order to destroy these inequalities and imperfections. For this purpose sheet-glass had to be made considerably thicker, owing to its never being perfectly flat throughout its length and width, so that one corner or another, and even several points on the surface, were liable to be completely worn out before the end of the operation.

Mr. JAMES CHANCE conceived the ingenious idea of laying every sheet of glass intended to be ground and polished, upon a flat surface covered with a damp piece of soft leather. The sheet adhering completely to the leather after having been pressed against, produces, in fact, a vacuum, so that by the pressure of the atmosphere the whole sheet is maintained in a flat position. Two sheets having been placed in this manner, each on the retaining or sucking surface, they are turned one against the other in a horizontal position, sand and water being constantly supplied between them; and by means of the most ingenious machinery, the two surfaces rapidly rub one against the other in all directions, and are ground at the same time by the sand. When the grinding has been performed on one surface, the sheets are turned to have the other surface ground in the same manner.

The sheet being ground while it is kept perfectly flat, it is not necessary to wear out more than a thin layer of the whole surface. Of course, after the operation, the sheet of its own elasticity resumes its former shape more or less curved, but the whole surface of both sides has a polish as perfect as plate-glass, and this is the desired condition for glazing purposes. Although the glass could not make perfect mirrors of a large size, on account of the slight curve arising from the flattening operation, still it may be usefully employed for small looking-glasses. M. CLAUDET states that this glass has all the perfection and qualities required for taking pictures by the collodion process, and for framing all photographic and other pictures, for which last purpose it is even preferable to cast plate-glass on account of its lightness.

Mr. JAMES CHANCE's invention is, therefore, one of the most important improvements in the manufacture of window-glass during the present century; and to him is due the cheap but beautiful glass now so generally used in glazing ordinary dwelling-houses—an article quite equal in effect to the expensive plate-glass which was formerly seen only in the windows of palaces and aristocratic mansions.

IV. PLATE-GLASS.—DODD justly remarks that a better name than *plate*-glass would be *cast*-glass, since the former is vague in its acceptation, and might be applied to any kind of glass in sheets, whereas the latter expresses the mode of manufacture of this beautiful article, which is formed by being *cast* or *founded* upon a smooth table while in a liquid state, and is totally independent of the process of blowing. It is not generally known, however, that originally all plate-glass was made by blowing; and that in this country it was not till 1773 that the British Plate-Glass Company first began to make plate-glass by casting, although this process had been in use in France for nearly a century. The method of blowing plate-glass was very similar in principle to that of sheet-glass, differing only in some mechanical contrivances to assist the workmen in handling so much heavier a piece. The plates formed by this method, however, were much smaller than can be executed by the casting process, which sometimes exceed ten feet in length, and are about half an inch thick. Plates have been cast as much as fourteen feet long by eight or ten feet in width, and some of enormous dimensions were shown at the Great Exhibition.

The principal consumption of plate-glass is for mirrors, the manufacture of which dates from the earliest introduction of glass-works into Europe. Mirror-glasses were for many years the object of an important commerce to Venice, the only city which could produce them. The manufactory, which was situated on the island of Murano, produced, however, only sheets prepared by blowing, and this was the process imported into France in 1665, along with the art of covering plates of glass with tinfoil, which had long been exclusively possessed by the Venetians. The largest mirror-glasses which could be made in this manner were about three feet in the side, and they were liable to the air-bubbles, knots, and striæ so frequent in common window-glass. All these disadvantages disappeared with the invention of the casting process which is now in use. ABRAHAM THEVART devised this bold method, as DUMAS terms it, and put it in practice at Paris in 1685. It was the same artist who founded in 1691 the celebrated manufactory of Saint Gobain in Picardy, which remained so long without a rival, and where perhaps the best plate-glasses are still made, though two or three other manufactories have been established on a very large scale, which renders the mirror-glass manufacture a very important object for France. In this country, as in France, the business is confined to a very few large establishments.

Composition of Plate-Glass.—This beautiful variety of glass is similar in composition to crown and sheet glass, the only essential bases being lime and soda; but in plate-glass the soda is introduced in somewhat larger proportion. So far as regards the purity of the tint, it would be attended with advantage to substitute potash for the soda; plate-glasses would thus be freed from the greenish or bluish shade which they sometimes present, and, in this case, one might increase the proportion of lime, which is kept comparatively low in plate-glass to avoid devitrification. But soda is preferred to potash for this description of glass, because it imparts a higher degree of fluidity, and because the impurities which it contains are more readily dissipated by the heat; so that the use of soda, though objectionable as tending to color the glass, facilitates both the fining and casting—two most important advantages in the manufacture. Subjoined is the analysis of a plate-glass by DUMAS:—

	Centesimally.		Oxygen.	
Silica, ...	75·9	=	39·4	
Alumina, ...	2·8	=	1·3	= 6·7
Lime, ...	3·8	=	1·0	
Soda, ...	17·5	=	4·4	
	100·0			

From this analysis it appears that the quantity of oxygen of the silica is about six times that of the aggregate oxygen of the bases. It will be seen, also, that this glass differs considerably from window-glass in the proportions; in the latter, for each equivalent of soda, there is always at least half an equivalent of lime, whereas, in plate-glass, for one equivalent of soda, there is only one-fourth of an equivalent of lime. In window-glass, putting the alumina and lime together, the oxygen of these earthy bases always exceeds the oxygen of the soda: in plate-glass the oxygen of the lime and the alumina constitutes scarcely the half of that of the soda. All these circumstances have the effect of rendering the plate-glass more fusible, more readily altered, and less hard than window-glass; but it is also less brittle, and less liable to be devitrified.

The preceding analysis is elementary and theoretical; the subjoined practical recipes are given in KNAPP's *Technology:*—

Composition used at St Gobain.	Composition according to Bastenaire
100 pounds pure sand from Senlis.	100 pounds white sand.
35 pounds pure salts of soda.	60 pounds salts of soda.
5 pounds lime, crumbled.	13 pounds carbonate of lime.
100 pounds broken glass.	100 pounds broken glass.
Decoloring matters.	1 pound peroxide manganese.
	0·5 pounds smalt.

The following proportions, which have been used in England, are said to produce a superior quality of plate-glass:—

	Parts.
Lynn sand, well washed and dried,	720
Alkaline salt, containing forty per cent. of soda,	450
Lime, slaked and sifted,	80
Nitre,	25
Broken plate-glass,	425

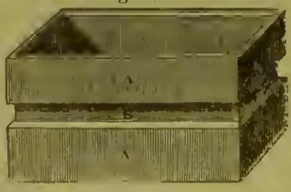
These quantities produce one pot of *metal*, which yields one thousand two hundred pounds of glass.

The object for which plate-glass is chiefly manufactured requires in the materials the highest degree of purification, and the utmost care in the fabrication. A good mirror should reflect an image in its true and natural shape, and no distortion must occur, which invariably happens if lumps or waves in the glass unequally refract the light or produce irregular reflection. Moreover, the light must pass through the thickness of the glass before it is reflected from the metallic surface at the back; and as the thickness of the plates must correspond with their lateral dimensions, which are often considerable, it is evident that transparency and absence of color are points of great importance. It is true that in the last century this was a disputed question. MONTANEY advanced that the black color was preferable to all others for mirrors, and his theory appeared so plausible as to require a formal refutation on the part of ALLUT. It is evident that, unless the light were assumed to be reflected at the first surface, this theory is quite untenable; and even assuming the reflection to take place at the first surface, it would be necessary to give the glass, not only a black color, but a complete opacity, similar to that of the metals themselves, of which mirrors were anciently made; but this absolute opacity, in the case of glass, would be very difficult, if not impossible, to attain.

In the present day the object aimed at, by universal agreement, is to give the most perfect transparency to mirrors, and to destroy the slightest traces of coloration. With this view, not only must the metal or melted glass be thoroughly fused, but the original materials must be selected with very great care. The sands which enter into the composition should be very white and fine. In default of suitable sand, soft sandstone, white and well pulverized, is used. Flint and quartz, calcined and reduced to powder, are excellent materials for the purpose. Particular care must be taken in the choice and treatment of the soda, to avoid, as far as possible, the green tint which is peculiar to glass formed with this alkali, and which the thickness of the plate-glass betrays. It might be possible to counteract this evil to a certain extent by a perfect fining or purification of the soda, and by replacing part of it with potassa, to the amount of about one-fifth. If plate-glass were formed with potassa alone, instead of soda, it is to be feared that a glass necessarily so rich in alkali, would be hygrometrical, and would partake too much of the nature of soluble glass. Even the small proportion of potassa which, in the shape of nitre, usually enters into the composition of French plate-glass is found to give it a dampness, so that when two of these are kept together for any length of time, they can scarcely be separated. Mr. VARLEY stated at a meeting of the Society of Arts, that he was once shown some very large glasses by a London manufacturer, which were beautifully clear, but appeared to be covered with steam, and this, when wiped off, appeared again. The manufacturer had applied to Professor FARADAY in hopes of learning how to cure this imperfection. On examining these glasses with a magnifier, the apparent steam was found to consist of very minute but long crystals, which shape indicated nitre, showing that so much potassa was used in the manufacture of the glass that it exuded. Now, repeated washings, which, with eight or ten feet glasses, is a serious labor, might much lessen the exudable matter; but the glass would thus become porous all over, and its power of transmitting or reflecting light would be diminished. What was still worse was, that such glass could never be wiped so as to remain clean, for the wiping filled up the pores with what should have been quite removed. This began again to exude in minute gummy dots, which continued to enlarge, and on again wiping, smeared the surface, rendering it difficult to clean. Soda is prone to dry and lose its water of crystallization; potassa, on the contrary, attracts moisture, and becomes liquid. Hence it would seem that soda must make the more durable glass, besides fulfilling the important conditions of rendering the vitreous composition more fusible and more easy to fine. The latter advantage arises from the fact, that the gall or sandiver of the soda-glass, consisting of sulphate of soda and chloride of sodium, is more volatile than potassa-gall, and is hence more readily got rid of from the open pots in which the glass is fused.

Melting and Fining.—Two sizes of pots are used in the manufacture of plate-glass—the larger for melting the vitreous mixture, and for keeping it long in a state of fusion—the smaller for receiving a portion of the glass to be fined and cast. The latter are termed cisterns, or in France *cuvettes*. The English pots and cisterns are of the same form as the pots used in the manufacture of crown-glass; and this is also the form of the French pot—Fig. 141; but in France the cistern or *cuvette* is formed square or rectangular—as shown in Fig. 170—and three pots contain the material for six small cuvettes, or for three large ones. These last are employed for mirrors of large dimensions—for example, of one hundred inches and upward. Latterly, furnaces have been constructed for six pots and twelve cuvettes, eight small and four large ones. The small ones have the form of a perfect square, the large ones of an oblong rectangle. About the middle of the depth of the cuvette, A A, a groove or indentation, B, is formed, whereby the vessel is grasped with the tongs.

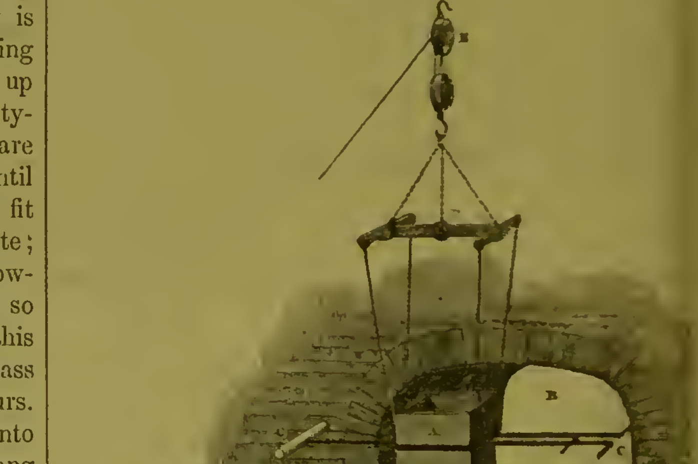
Fig. 170.



The ingredients for plate-glass were formerly fritted before melting; but this preliminary process is now dispensed with, the mixture being composed of such pure materials that it can be placed cold in the pot in three successive charges. The time necessary for the fusion and the fining is in France divided equally between the pots and the cuvettes. The material is left sixteen hours in each, and, at the end of these thirty-two hours, it is fit to be cast. During the melting of the mixture in the pots, the cuvettes are placed empty in the furnace; but as soon as the whole charge is in a state of fusion, the cuvettes are removed by means of tongs, and cleansed from all impurity, and from the residual glass of the last operation by a scraper. They are then replaced in the furnace, and after a few moments' heating, the ladling or transferring operation commences. The surface of the metal in the pots is skimmed, and the liquid glass is transferred into the adjacent cuvette with a copper ladle, care being taken not to disturb any grains of sand or lumps that may have settled down at the bottom of the pot Thus, as **KNAPP** remarks, at the very commencement a kind of double purification is effected—the infusible portion is left untouched, and the glass is well mixed by the agitation of ladling. This transferring process, which is termed in France *tréjetage*, requires two workmen, one after the other; each draws out the glass three times—whence the word *tréjeter*, to throw or cast thrice—and then plunges his ladle into cold water. The furnace is then shut, and the cuvettes are left to themselves, for the glass to fuse—that is to say, that the bubbles excited in the mass by the *tréjetage* may be disengaged, and the excess of soda be entirely volatilized. It has been stated that the melting is generally accomplished in sixteen hours; but the fining which succeeds the ladling process must be kept up quite as long, and extends indeed sometimes to twenty-four or even forty-eight hours before the bubbles are dispersed and no more alkali is volatilized, or until specimens of the glass exhibit in every respect a fit state for casting. This is not exactly a liquid state; but after the perfect melting has taken place, the glowing mass is allowed to lower its temperature a little, so as to acquire a slight degree of viscidity. With this view the fire is allowed to decline, and the glass acquires the proper consistency in three or four hours. To make sure of this, the end of a rod is dipped into the cuvette; the portion taken up is allowed to hang down, and by the form it assumes and other indications, the workman readily judges whether it has acquired the necessary consistence and is free from bubbles. This is termed *drawing the glass*.

Casting.—While the glass is acquiring the requisite consistence, attention must be given to heat the annealing furnaces, as well as the casting-slab or metal plate which is to receive the liquid glass. This table was formerly made of bronze; but the liability of this metal to crack induced the British Plate Company to try a plate of cast-iron, which was found to be quite successful, and even the large bronze slab at St. Gobain, which weighed fifty thousand pounds, and cost one hundred thousand francs, or £4000, has been discarded, and replaced by one of iron. The table, T T—Fig. 171—must be of longer dimensions than the largest plate; it varies from ten to twenty feet in length, with corresponding breadth, and is six to seven inches in thickness; it rests on a strong wooden frame or truck, M M, movable on casters, and sometimes running on a railway, along which it is wheeled from one annealing oven to another, since it is necessary that the table should be placed close to the oven or arch, B, into which the plate is to be removed for annealing after being cast. With this view the height of the slab or table is made exactly on a level with the floor of the arch. Its upper surface is flat and polished, to mould the lower surface of the mirror; and, before the casting, it is heated by hot coals spread over it, and then wiped perfectly clean.

Fig. 171.



The annealing-ovens being heated to a brown-red, the casting-slab brought to a suitable temperature, and the metal or melted glass thickened to the requisite point for flowing readily and equably, the aperture into the cuvettes which are to be taken out is then opened; two workmen introduce tongs into the furnace, and grasp the cuvette by the groove shown in Fig. 170, while a third slides a large pincer under it. When this instrument is pushed well under the bottom of the cuvette, the workman draws it towards him, aided by the others with their tongs, which are supported on rollers. In this manner the cuvette is drawn to the mouth of the opening, where it is raised by a crane, placed upon a truck or low carriage, and removed to the casting-table. The melted glass being skimmed, the cuvette, A—Fig. 171—is then drawn up to a sufficient height by the tackle, D E, and suspended above the upper end of the casting-table, where it is tilted over by means of the tongs, C C, and the metal is poured out on the table. The appearance presented by the molten sheet is now exceedingly splendid. The building being very dark within, the glowing liquid throws a strong light on the faces and persons of the workmen. In the meantime, the glass is prevented from running over the sides by ribs or rims of copper, N N, which are exactly equal in height to the intended thickness of the plate of glass; and when the cuvette has been emptied of its contents, a massive hollow copper cylinder, F, three feet in diameter, and resting at each end on the side ribs, is set in motion. This cylinder, which weighs several hundredweights, is moved by means of the handles which form a prolongation of the axis, and spreads the glass out into a sheet of uniform breadth and thickness. It would, however, overflow the sides, if this were not prevented by the workmen applying the iron pieces, G G, which form a dam at the sides, and precede the course of the rollers. Lastly, to prevent any impurity from contaminating the glass, a workman draws the washer, H, covered with cloth, immediately in front of the advancing sheet of fluid glass; the excess of glass pours over the front edge of the slab into a trough, K, filled with water, and finally the roller passes off and is received in the grooves, I I. A beautiful play of brilliant colors, comprising every imaginable tint, is exhibited by the glass immediately after the roller has passed over it; caused, probably, by a temporary oxidation of the surface.

Whilst the cuvette is carried back to the furnace to receive a fresh charge of glass, the two ribs are removed, and any blisters or seams or redundancy which may exist at the two sides of the plate are broken off; a thick flange of the still soft glass is then turned up at the end, T T, and a rake-shaped iron is applied to it, by means of which the plate is thrust forward into the annealing oven, B, where it rests upon sand. As the plate is not perfectly rigid when this is done, the force which must be exerted to push it over the floor of the kiln often produces considerable undulations on the upper surface, which subsequently disappear under the polishing.

While the introduction of the plate into the annealing arch is being proceeded with, other workmen are engaged in taking from the fining furnace another cuvette, which arrives at the casting-table at the moment when the preceding plate has just been introduced into the annealing oven. After filling the oven, all the openings are carefully stopped up with iron plates and clay mixed with sand. At the end of twenty hours, some of the pieces of iron are taken away; an hour or two afterwards more are removed; as the oven cools, more and more are taken away, and at last the whole of the clay and plates of iron which stopped the apertures are removed. When the hand can be placed on the glass plates without feeling much heat, they may be taken out of the oven. Such, at least, is Dumas' account of the French method. But in this country the plates are allowed to remain in the oven, resting in a horizontal position, from five to ten days.

It has been stated that the temperature of the annealing kiln, when the plates are introduced, should be a dull red. If the kiln were too hot the plates would enter into a state of semi-fusion, and would get out of shape, or at least would adhere to the floor of the kiln, so that they could not be detached without breaking. On the other hand, if the kiln were too cold, the plates would be badly annealed, and might fly to pieces in the act of being taken out of the oven, or afterwards. The slightest change of temperature is sufficient to split into pieces plates which have been badly annealed. They break also when one proceeds to cut off the jagged edge with a diamond. It almost always happens that, in plate-glasses badly annealed, the separation does not occur at the place where the incision has been made.

The annealing ovens, termed in France *carquaises*, are very large, and have several fire-places. The bed or floor is made of bricks, presenting in its whole extent a perfectly level surface. Sand must be sprinkled over the bed, that the plates may slide freely upon it, and encounter no impediment in shrinking or contracting.

Squaring, Grinding, and Polishing.—After being withdrawn from the annealing oven, the plates have to undergo the operations of squaring, grinding, and polishing. As taken from the oven, they are about half an inch thick, and present an irregular mottled appearance, roughened on the lower surface by the sand on which they have rested, and smoother, but not flat on the upper surface. The first process is that of squaring, or cutting them into their useful dimensions; for which purpose they are carefully examined, and the workmen endeavour, notwithstanding the imperfect transparency of the glass, to select those which appear to be free from defects, to be reserved for large plates, while such as show imperfections that cannot be removed by grinding, are picked out to be cut into smaller plates, transposing the faulty parts to the sides. The squaring is performed by passing a rough diamond along the surface of the glass, guided by a square rule; the diamond cuts to a certain depth into the substance, when, by gently striking the glass with a small hammer, underneath the part which is cut, the piece comes away; and the roughnesses of the edge then left are removed by pincers.

The plates having been squared, next undergo the processes of grinding and polishing. In these operations two plates are employed, one of larger dimensions, and one three or four times smaller, which are made to rub against each other. This was formerly done by hand, but is now almost entirely performed by machinery. The lower and larger plate is embedded in plaster of Paris, in a perfectly horizontal position, upon a table about two feet high, which is termed the *grinding bench;* the smaller plate is cemented upon the lower face of a swing table, made heavy by weights, and caused to traverse over the lower plate in such a way, that by a combination of a rotatory and oscillating motion, the relative position of the two plates is constantly changed. In adjusting the plates, a rough or rolled surface of the one is opposed to the comparatively smooth or casting-plate surface of the other, and the material employed to grind the surfaces is thrown upon the lower plate from time to time. River sand and water were formerly used for this purpose, but ground flint of different sizes is now substituted, as answering the purpose better. The machinery is set in motion by a steam-engine, and this process is continued until the ground plates exhibit a perfectly horizontal and even, though still unpolished surface. When one side of each plate has been sufficiently ground, it is loosened from the frame and turned over, so as to present the other surface to be ground in the same manner. Some degree of pressure is employed by loading the upper plate with weights, as the grinding of each side approaches to completion. The process thus described used formerly to last three days, but the time is now much abridged. The greatest attention is required to complete the operation, with the surfaces perfectly level and parallel, for which end a rule and plumb-line are employed.

By means of this grinding, the plates are made level, but are still too rough to receive a polish. To fit them for this, they are now ground with emery powder of increasing degrees of fineness. When the plates become sufficiently smooth for this operation, there is a tendency to cohesion between the surfaces, which produces so much friction that when the work is done by machinery one surface will frequently tear the glass from the other. Hence hand labor has been generally employed in this part of the process. The lower plate is placed upon a stone bench covered with wet canvas, which holds it firmly in its place; the surface is sprinkled with emery and water, and a small plate, moved by the hand, is used as a runner or grinder. Women are generally employed in this operation, and are said to perform the work better than men, on account of their superior delicacy of touch, which enables them to use precisely the degree of force required, and readily to detect and remove gritty particles among the emery. Young girls are employed on small plates. About three sizes of emery are used, the different qualities being previously separated and assorted by suspension in water; and between every size the plates, canvas, bench, and hands are thoroughly washed. After the application of the last or finest emery, the plate has become quite smooth and partly polished. To dispense with the necessity of manual labor in this operation, Mr. BLAKE, of the Thames Plate-Glass Works, has recently introduced a machine which imitates the motions of the arms of the persons employed in smoothing, and works admirably.

The glass, although now perfectly even, appears opaque and deadened on the surface, and still requires the final polishing. To effect this, a piece of wood is covered with numerous folds of woollen cloth, having carded wool interposed between each two layers, so that the whole forms a tolerably hard but elastic cushion, which is fitted with a handle. The plate is embedded in plaster, as already described, and the cushion, being wetted, is covered with Venetian pink, which contains a small portion of oxide of iron, mixed with earthy matter, and is moved backwards and forwards on the surface of the plate, with considerable pressure. This rubbing is now generally performed by machinery, as hand-polishing is tedious, and is apt to produce a wavy appearance; hence machine-polished glass is to be preferred.

In 1856, a patent—communicated by ALBERT BROUGHTON, ALEXANDER LINDSAY, and JOHN RUTHVEN PLATT, all of New York—was taken by WILLIAM EDWARD NEWTON, of the Patent Office, Chancery Lane, London, for an improved method of polishing the surface of glass, stone, metal, or other materials capable of being polished by friction. The distinguishing principle of this method consists in grinding and polishing the flat surfaces by means of a rotating plane of glass, metal, stone, or other suitable material, the substances of which the surfaces are to be ground or polished being held in a frame in such a manner, that the friction, exerted by the rotating plane upon the surfaces of the substances under operation, will cause them to rotate with a slower motion upon their own centres. The form adopted as most convenient for the grinding and polishing surface is circular; it therefore generally consists of the upper surface of a circular table or wheel, which may be of cast-iron, and is secured firmly at the upper end of a vertical shaft, which is supported in suitable bearings in a strong framing of timber or iron. The upper end of the shaft is not allowed to stand above the table, and therefore the article to be polished will be allowed to pass over its centre. Rotary motion is communicated to this circular table by means of suitable gearing. The apparatus for holding the plate of glass to be ground and polished consists of a plate or frame of metal or wood, having a rim all round the lower side, within which the glass is received in a bed of plaster of Paris. This plate or frame is connected with a perpendicular spindle which is capable of being moved nearer to or further from the centre of the rotating circular table. The grinding and polishing operation is effected with the aid of sand, or any common polishing material. To commence the operation, the plate of glass, having been secured in its bed or frame, is placed on the rotating circular table, and the holding plate or frame is connected with the long lever by means of its spindle. Rotary motion is now given to the circular table, and when the sand or grinding material is properly distributed, the friction produced on that part of the plate of glass which is at any time on that side of the spindle of the holding frame which is furthest from the centre of the table, being greater than that on the part which is at the same time on that side of the spindle nearest the centre of the table, causes the plate to rotate in the same direction as the latter. The sand or grinding material, when a fresh supply is applied, will always distribute itself evenly after a very few revolutions. The grinding may be regulated by a screw and nuts on the spindle of the holding frame, so as to produce a pressure on the plate, additional to what is produced by its own weight, and the weight of the plate or frame and other parts of the holding apparatus, or to take off some of that pressure. The patentee alleges that, by producing the rotary motion of the glass to be ground and polished, by means of the friction of the grinding or polishing surface, an evenness and smoothness and freedom from scratches are obtained, that cannot be produced when the rotary motion is positive, or produced by gearing, as in other polishing machines. The reasons assigned for this are as follow:—In the former case, the grinding or polishing surface and the surface to be ground or polished undergo an infinite transposition, while in the latter, they are frequently in precisely the same relative positions; again, when the motion is produced by friction, it is found to be steady and free from the tremor which is produced when an independent and positive motion is given.

The Editor is informed by Mr. FINCHAM, the active and intelligent manager of the British Plate-Glass Works, that the preceding process acts admirably, and is sure to supersede all those hitherto in vogue. It is daily working under Mr. FINCHAM'S superintendence.

Mr. BESSEMER some years ago proposed a new method applicable to the whole process of casting, grinding, and polishing plate-glass. Dispensing with the use of cuvettes, he pours the melted glass directly from the pots between two rollers, placed at a certain distance apart, and kept cool by a current of water passing through them. This insures a uniform thickness in the glass. The furnace employed by Mr. BESSEMER is a reverberatory with a low arch, and the pot, which is of very large dimensions, is set upon a movable siege composed of masses of firestone firmly cemented together. The pot and siege run upon four wheels, by means of which they are readily moved out of the furnace, to empty the contents of the pot between the two *forming* rollers already alluded to, and, after passing between these, the glass is received between two *finishing* rollers placed closer together, and moving with accelerated speed, so that, on emerging from the latter, the glass appears smooth and flat, though wanting in polish. The plate now slides down a curved surface upon a flat table, and, when sufficiently cooled to become rigid, it is transferred to the annealing kiln, which is heated by a current of hot air obtained from a chamber situated between the furnace where the glass is melted and the chimney. A saving of fuel is thus effected, the heat is more easily regulated, and the articles to be annealed are not subject to injury from the dust and products of combustion of the fuel. The polishing, according to BESSEMER's method, is performed by laying the plate of glass upon a slab of slate placed perfectly horizontal upon a bed of brick-work, and causing an endless belt of gutta percha, covered with felt and polishing material, to pass rapidly over the surface of the glass in contact therewith, and to traverse at the same time slowly across the plate by a lateral motion at right angles to the line in which the belt moves over its drums. The belt is of the same length as the sheet to be polished, and is pressed upon the entire surface of the glass by a number of small rollers. The continuous action of the strap in one direction renders it unnecessary to cement the glass to the table, which is effectually prevented from shifting its position by a raised rib or stop let into one end of the table.

By the grinding and polishing, the plates are reduced in thickness as much as one-third, and in some cases one-half. If any radical defects exist in the glass, these are only heightened by the polishing, and hence a second and more careful examination and selection of the plates is now made. In fact, in every stage of the manufacture, the experience of the workman is called for, to determine whether any and what imperfections appear, and how they are to be removed; and as, on the one hand, no manufactured article would betray the existence of defects more readily than a large sheet of plate-glass, so, on the other hand, the most sedulous attention is paid to the detection of such defects when they appear in the course of the manufacture. Those which are still found defective after the polishing, are cut up into smaller plates, and polished again, while the perfect ones, when destined for mirrors, are subjected to the final process now to be described.

Silvering of Mirrors.—This designation is a misnomer, there being no silver used in the common method of performing the operation; but a compound of tinfoil and mercury, or quicksilver, whence probably the mis-appellation. The operation is commenced by spreading a sheet of tinfoil, which must be of somewhat larger dimensions than the plate to be covered, upon a flat stone or slate slab, termed the *silvering table*, and brushing mercury over it. When the surface of the tinfoil is uniformly covered, more mercury is added till it covers the metallic sheet to the depth of one-sixth or one-fourth of an inch. A brilliant surface is then produced upon the fluid metal, by skimming aside the grey coating of oxide with a wooden rod. The plate of glass is now introduced by pushing it forward horizontally from one side of the table, with the longest edge foremost, and so that this edge always dips below the surface of the mercury. By this means dust and air are totally excluded; whereas, if the plate were let down perpendicularly upon the mercury, more or less of both would certainly be enclosed between the glass and the amalgam. On the contrary, by sliding it forward in the manner described under the surface of the mercury, the pure metal alone is brought into contact with the glass. To get rid of the excess of quicksilver, the plate or mirror is loaded with weights, and the table is inclined at an angle of ten or twelve degrees, when most of the uncombined mercury flows away. The last portions are removed by placing the plate in an upright position, and in the course of three or four weeks a dry permanent coating of tin amalgam is left on the glass.

A great disadvantage attending this operation is the serious detriment to the health of the workmen from the vapor of the mercury; another objection is the very considerable time required to complete the work; and, lastly, the process is subject to frequent failure from different causes: the plates often break under the pressure of the weights, and, when set on edge, drops of mercury sometimes trickle down, and carry the amalgam with them, producing curved streaks, technically termed *worms*, so that it becomes necessary to re-silver the whole mirror. The amalgam, also, is liable to spoil by crystallization, and is easily injured by carriage. A process proposed by DRAYTON, and tested by FARADAY and WARINGTON, is free from these defects. It consists in employing a *silvering fluid*, obtained by mixing ammonia with nitrate of silver, filtering the mixture, and adding to it an alcoholic solution of oil of cassia. The proportions are one ounce of nitrate of silver, three ounces of alcohol, of the strength of 87 per cent., and twenty to thirty drops of cassia. This fluid has the property of depositing *bright metallic silver* on the addition of what is termed the *reducing liquid*, consisting of a solution of one part oil of cloves in three parts alcohol. The term *silvering* is, therefore, strictly applicable to this process, which is performed by surrounding the plate of glass, after being perfectly cleaned, with a rim of putty, and pouring upon it a layer of silvering fluid to the depth of one or two lines. The oil of cloves solution is then added, and, more or less rapidly, in proportion to the quantity of this solution employed, a film of brilliant metallic silver is deposited, and attaches itself firmly to the glass. The coating succeeds best when a very small portion of the reducing liquid is used, so as to cause the reduction to proceed slowly. To cause the precipitation of four and a half ounces of the solution of silver, from six to twelve drops of the reducing liquid are sufficient; and so thin is the film of metal thus deposited, that a square foot of it only weighs from twelve to eighteen grains. The principle of the process consists in deoxidizing the oxide of silver, by means of the volatile oil, which is effected without any evolution of gas, that might destroy the continuity of the metallic coating, while the nitric acid disengaged from the oxide of silver enters into combination with the ammonia.

Great as may appear the advantages of this process, it has not been applied extensively by the manufacturers of mirrors, partly on account of the difficulty of obtaining, by this means, a perfectly clear unspotted surface, and partly on account of the darker color of the silver coating, which gives a black effect to the mirror. This black appearance is probably due to the shade of the silver, although it has been also ascribed to the very perfection of the coating, and the precision with which it reflects the rays of light, whereas the ordinary coating of tin amalgam is crystalline, and reflects the light to the eye in almost any position.

The mixture now employed by Mr. DRAYTON is somewhat different from that above given, and consists of one part of ammonia, two parts nitrate of silver, three parts water, and three alcohol; this solution, being filtered, is mixed with one-fourth part of grape sugar dissolved in weak spirit. This method, or one very similar, is stated by PELOUZE and FREMY to be now successfully practised at Paris. The exact proportions given by them are as follow:—Six hundred grains of pure neutral nitrate of silver are dissolved in one thousand two hundred grains of water. To this solution are added:—First, seventy-five grains of a liquor prepared from twenty-five parts of distilled water, ten of sesquicarbonate of ammonia, and ten of ammonia, of specific gravity 0·980; second, thirty grains of ammonia, specific gravity 0·980; and, third, one thousand eight hundred grains of alcohol, specific gravity 0·850. The mixture is left at rest to become clear. The liquid is decanted or filtered, and a mixture of equal parts of alcohol—specific gravity 0·850—and of oil of cassia is added in the proportion of one part of this *essence of cassia* to fifteen parts of the argentiferous solution; the mixture is agitated and left to settle for several hours, after which it is filtered. Just before pouring it upon the glass to be silvered, it is mixed with one-seventy-eighth of its bulk of *essence of cloves*—composed of one part of oil of cloves, and three of alcohol, specific gravity 0·850. The glass having been thoroughly cleansed, is covered with the silvering liquid, and warmed to about 100°, at which temperature it is maintained for two or three hours; the liquid is then decanted, and may be employed for silvering other glasses. The deposit of silver upon the glass is washed, dried, and then varnished.

VOHL proposed to form the silver coating for the interior of glass balls, *et cetera*, by dissolving gun-cotton in caustic potassa, with the aid of heat, adding to the brown solution a few drops of nitrate of silver, and the ammonia, until the precipitated oxide of silver is re-dissolved. This mixture is introduced into the glass ball, or other article to be loricated, and heated in a water-bath, when, after a certain time, the mixture becomes blackish-brown, froths up, and deposits all the silver upon the glass, forming a mirror which is said to reflect the light with surpassing brilliancy.

V. FLINT-GLASS.—This compound, which is commonly termed *crystal*, from its great resemblance to the natural production known as rock-crystal, is chiefly manufactured into articles of domestic use and ornament, such as tumblers, decanters, wine-glasses, vases, drops for chandeliers, *et cetera*. In consequence of its great transparency and high refractive power, it is also formed into lenses for optical instruments. On the Continent the term flint-glass is almost exclusively applied to glass which is expressly manufactured for the latter purpose, and *crystal* is employed as the more comprehensive designation for glass containing lead, of which flint or optical glass is regarded as a variety. In this country, flint-glass and crystal are used as synonymous terms, and that particular variety of this description of glass which is manufactured for optical purposes is termed *optical glass*.

Flint-glass is so called from the circumstance that formerly, flints calcined and ground were employed in the manufacture as the source of the silica: but for many years past, Isle of Wight, Lynn, or Reigate sands have been substituted. These sands are not only more free from iron, but less expensive in the preparation than flints, when washed and calcined. Not only in this respect is the name inapplicable. To convey a correct idea of its composition, it ought to be termed lead or metallic glass, as the presence of a new element, *lead*, is that which distinguishes flint-glass or crystal from the different varieties of glass already mentioned. It is also distinguished from English crown and plate-glass by the use of potassa, instead of soda, in the manufacture.

DUMAS remarks that, by all the old writers, colorless glass, whatever be its nature or composition, is designated indifferently under the name of *crystal*. Thus, under this common designation, were confounded glass with a simple base of potassa, glass with a base of potassa and lime, and lastly, glass with a base of potassa and lead. It is necessary to be aware of this confusion, if one wishes to read with profit the old works on glass-making. At the present day, the term crystal or flint-glass is reserved to denote the double silicate of potassa and lead employed for the purposes already mentioned.

This beautiful variety of glass is admitted on all hands to be of English origin. Its invention was a natural and almost necessary consequence of the use of coal in the English manufactories—a usage which goes back to a very remote epoch. To prepare white glass in an open pot, with coal as fuel, is a problem which admits of being solved at the present day, but which could not be so at an early period. To protect the glass from the contact of the smoke which blackened it, it was necessary to convert the common pot into a retort with a short neck, which presented its mouth outside the furnace. But under this condition, the vitrification became too difficult for ordinary glasses; it would have been necessary to increase beyond measure the proportion of alkali. It was essential, therefore, to find the means of increasing the fusibility of the glass, without rendering it deliquescent; and this was accomplished by means of a suitable addition of protoxide of lead. The beauty of the product soon assigned it a high rank among the different varieties of glass, and the manufacture of it was not long in extending even into countries where coal is not used. But in these localities the manufacture could be conducted in common pots, taking care to manage the wood fire, so as to avoid all production of smoke, and modifying slightly the proportion of the substances employed.

Flint-glass, however, is not entirely a modern invention, or, at least, if it was necessary to re-invent it, it is certain that it was known at a very remote epoch. This is demonstrated by the analysis of the ancient glass known as *Virgil's mirror*, an operation performed in 1787 by M. FOUGEROUX DE BONDAROY. This mirror, weighing thirty pounds, polished on both faces, transparent, but colored a yellowish green, contained at least half its weight of oxide of lead, and exhibited, moreover, all the characters of crystal. It had been preserved in the treasury of Saint Denis in France from the time of its fabrication, which assigns to its manufacture an epoch long anterior to the discovery of modern crystal. It is evident, indeed, that the name applied to the mirror is not correct, and proves nothing—that it did not belong to VIRGIL, and that it could not claim an antiquity so remote. This article only proves that the method of making lead-glass had been long known, and that the processes of the manufacture must have been well understood, since at that time a mirror could be formed of a size which would be deemed remarkable even at this day, and that the secret had been lost during a long succession of years. It may be affirmed, indeed, that the *colorless* crystal or lead-glass of the present day, or, in other words, a crystal possessing that quality which constitutes its chief beauty and value, is entirely of modern invention. It is very natural to suppose that the method of making a colored crystal like Virgil's mirror might be known to many mediæval chemists, without assuming that they equally knew how to prepare a pure and colorless crystal like that now manufactured under the name of flint-glass.

Composition and Properties of Flint-Glass.—Five elementary analyses of crystal or common flint-glass have been given at page 192. The table in the same page, in which flint-glass is associated with strass and enamel, refers to that variety of flint-glass known as optical glass. From the former analyses it will be seen, that the composition of common flint-glass, after deducting the extraneous constituents, may be expressed by the following formulæ:—

I. $KaO, 2\,SiO_3 + 3\,(PbO, 3\,SiO_3)$.
II. $3\,(KO, 3\,SiO_3) + 4\,(PbO, 3\,SiO_3)$.
III. $2\,(KO, 2\,SiO_3) + 3\,(PbO, 2\,SiO_3)$.
IV. $3\,(KO, 2\,SiO_3) + 3\,(PbO, 2\,SiO_3)$.
V. $KO, 2\,SiO_3) + PbO, 2\,SiO_4)$.

In one case, therefore, triple silicates are the proximate constituents of the glass; in the others, double silicates. In fact, the proportions of the three essential constituents, namely, silica, potassa, and oxide of lead, vary according as the melting furnace is heated with wood or coal. In the latter case, the proportion of oxide of lead is increased. The following analysis by DUMAS has been already given at page 192, but is here repeated, to show the proportion of oxygen in the bases, as compared with that of the silica or silicic acid.—

	Centesimally.	Oxygen.	
Silica,............	56	.. 29	
Lime,............	2·6	.. 0·72	4·47 oxygen of the bases.
Oxide of lead,......	32·5	.. 2 25	
Potassa,..........	8·9	.. 1·50	
	100·0		

Here the oxygen of the bases is to that of the acid as 1 : 7. In the following analysis by M. BERTHIER, of a Vonêche crystal made with coal as fuel, tho proportion is nearly 1 : 9:—

	Centesimally.		Oxygen.	
Silica, ...	61·0	=	31·7	
Oxide of lead,....	33·0	=	2·3	3·3, oxygen of the bases.
Potassa,.........	6·0	=	1·0	

These two analyses show, beyond all doubt, that the law of saturation of crystal or lead-glass varies within wide limits.

Many metallic oxides are capable of combining with silicic acid, and thus furnishing silicates which readily mix with alkaline silicates; but almost all these are colored. Till lately, the protoxide of lead and the oxide of bismuth were regarded as the only oxides capable of yielding silicates with little color, and, consequently, colorless glasses, by their mixture with the silicate of potassa in a proper proportion; but a *glass of zinc*, which had a very pleasing and white appearance, and was specially suited to achromatic purposes, was the subject of a reward at the Great Exhibition of 1851. This glass had the remarkable property of being of greater specific gravity, and much more pure and pellucid than lead-glass. It is to be expected, therefore, that the former may come into general use. On the contrary, the oxide of bismuth is much dearer than that of lead, and hitherto the latter has been alone employed in the manufacture of common crystal.

Crystal or flint-glass well prepared is almost without color. It is more transparent, more brilliant, and heavier than plate or window-glass. It excels the fine Bohemian crown-glass in refractivo power and easy fusibility, although the latter is harder and more completely colorless. Flint-glass, of not less than the usual density of 3·200, well polished by the lapidary, is considered the nearest approach to the diamond. It owes its brilliancy and high density to the silicate of lead; but as the latter is itself yellow, it communicates a yellowish tint to the crystal when it preponderates over the alkaline silicate beyond a certain limit. There is also another reason for avoiding to use too much of it. The silicate of lead is much softer than the alkaline silicates. In too large quantity, therefore, it renders the glass so easy to scratch by the slightest friction, that it could not be employed for most of the articles of domestic use or luxury into which it is fashioned. Moreover, this addition rendering it both heavier and more costly in the manufacture, would be at least useless, even if it were not absolutely prejudicial, for the reasons already mentioned. It is a common mistake to suppose that great density or *weight* is an advantage in crystal for articles of common use. It is, on the contrary, as DUMAS justly remarks, a real inconvenience, and, in the most favorable view, can only be considered as a ready means of showing that the crystal or flint-glass contains enough of silicate of lead to impart to it all the other qualities which give it its peculiar value, and render it preferable to other glasses for certain purposes.

As lead affords the only metallic oxide which is usually employed in the manufacture of flint-glass, so potassa is the only alkali which can be successfully associated with that ingredient to yield a colorless crystal. The silicate of soda always communicates a blue or green tinge, which would become more perceptible and disagreeable in the thick articles usually manufactured of crystal. If this thickness were much reduced, the silicate of soda might, so far as color is concerned, be used in the manufacture; but as crystal vessels are generally intended to receive mouldings or cut ornaments, they do not admit of being made thin in the sides. The annealing, also, would become a difficult operation in vessels of considerable size without a proportionate thickness. Crystal is so fusible that it is not easy to prevent such articles from sinking in, or collapsing, during the annealing. This kind of glass is, therefore, almost exclusively confined to the manufacture of thick articles; and hence it is only the colorless silicates that can be used—that is to say, those of lead, or zinc, and potassa. It is stated, indeed, that M. BONTEMPS uses soda instead of potassa, or a mixture of the two, in his recipe for optical glass; but this is an exception to the general rule, and requires explanation. The following practical recipes are given by M. BASTENAIRE for a good common flint-glass, the one with coal, and the other with wood as fuel:—

	With coal as fuel.	With wood as fuel.
	Pounds	Pounds.
Sand—washed and calcined,	100	100
Minium,	70	45
Purified potassa,	30	35

In addition to these, cullet or broken glass is added at discretion, and saltpetre or arsenic is used as a decoloring material. It will be seen that, when coal is used, the sand, red lead, and potassa are nearly in the proportions of 3 : 2 : 1; but that, when the composition is fused in open pots, with wood fuel, the proportion of the red lead is much diminished. The following composition, in which the above-mentioned proportions of the principal ingredients are exactly adhered to, is given by Mr. APSLEY PELLAT, as yielding a highly pellucid and transparent flint-glass:—

Carbonate of potassa,	one hundredweight.
Red lead, or litharge,	two hundredweight.
Sand—washed and burnt,	three hundredweight.
Saltpetre,	fourteen to twenty-eight pounds.
Oxide of manganese,	four to twelve ounces.
Cullet, or broken glass, *ad libitum*.	

Such is the most common proportion; but DUMAS affirms that a finer and more durable product is obtained by reducing the amount of alkali; thus, for three hundred parts of sand and two hundred of minium, ninety to ninety-five parts of purified carbonate of potassa, instead of one hundred, will yield a better result when the furnace draws well—in winter for example. But in summer, the preceding proportions must be used, or the following French recipe:—

	Parts.
Pure sand.	300
Minium,	215
Purified carbonate of potassa,	110
Nitrate of potassa,	10
Borax,	12

It has been stated, that when open pots are used, as on the Continent, with wood fuel, the proportion of minium may be reduced. This arises from the circumstance, that the oxide of lead, being an active flux, is less necessary for the fusion in uncovered pots, which admit of the direct action of the heat on the contained mixture or metal. However, the use of the three essential ingredients in the ordinary proportion of three, two, and one, is, in all cases, a safe one. It is chiefly for economy that the minium is reduced in amount, when the heating power of the furnace is sufficient to permit the reduction. On the other hand, if the minium be too much reduced, the beauty of the product will suffer. The lowest proportion of this ingredient which can be used with safety is shown in the following composition, which yields a good crystal:—

	Parts.
Sand,	300
Minium,	180
Purified carbonate of potassa,	120
Cullet,	300
Arsenious acid,	0·45
Oxide of manganese,	0·60

The mere due proportioning of the materials for flint-glass is not sufficient—the utmost attention must be given to have them in a state of purity. The silica or sand should be very white, and absolutely free from coloring oxides, as those of iron or manganese. Some manufacturers cleanse the sand by hand-washing, and others have machines. To render the Isle of Wight sand fit for making flint and other compound glasses—that is to say, to cleanse it from chalk and other impurities, by which it loses about one-fifth of its original bulk, requires about eight waters; it is afterwards passed through a heated arch, called a *calker*, and thoroughly dried, or burnt, at the discretion of the operator; and then sifted through a lawn-sieve, to separate the larger grains and pieces of coal or coke. DUMAS recommends that the sands be washed with dilute hydrochloric acid, to remove from them any traces of oxide of iron or of manganese.

The carbonate of potassa also requires a preliminary purification, which is easily effected by dissolving it in water, decanting the quite clear solution, and evaporating the liquor. All the coloring oxides are deposited, and by the evaporation carbonate of potassa is obtained, mixed with other salts, but at least quite free from oxides of iron or of manganese. If the nitrate of potassa were low in price, one might employ it to replace the carbonate.

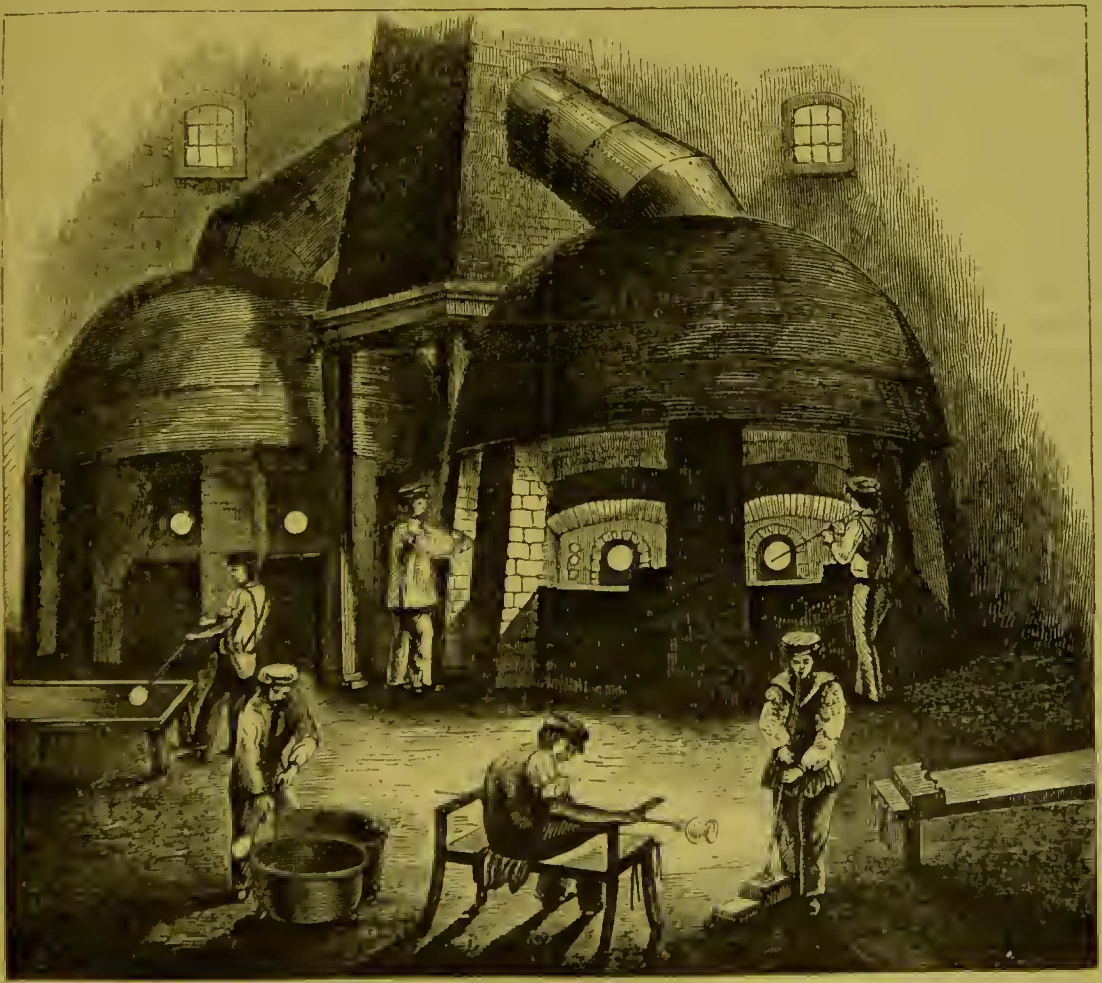
The protoxide of lead, or litharge of commerce, is almost never pure. It contains oxides of copper, of iron, or of manganese, in too great quantity, in most cases, to admit of its making a colorless flint-glass. Moreover, an oxide of lead is expressly manufactured for the making of crystal. In general, there is selected for this purpose a very pure lead, which is carefully oxidized, to avoid introducing into it foreign and injurious matters. It is the practice to carry the oxidation of the lead to the state of *minium* $Pb_3 O_4$. Not that the crystal contains red lead; the latter loses by the action of the heat a portion of its oxygen, and passes again to the state of protoxide which alone forms part of the glass. But it is advantageous, and probably even indispensable, to furnish to the mixture which is to produce the flint-glass a body capable of yielding oxygen at the beginning of the fusion.

It has been supposed that this disengagement of oxygen was necessary to produce in the glass the agitation which prevents this product from separating itself in layers of different densities. But DUMAS observes that the decomposition of the minium must be concluded long before the fusion is effected. The oxygen which the minium disengages has very probably, for its object, to burn an organic matter analogous to ulmin, which is found in large quantity in the crude salt; a matter which is decomposed in part, calcining this last to make potassa of it, but which is still found in the potassas of commerce in notable quantity. This matter, put in contact with the protoxide, would reduce it to the metallic state, and would color the crystal; whereas, being burned by the oxygen of the minium, it disappears, without leaving a trace of its existence.

It is evident that the same result would be arrived at by using nitrate of potassa instead of the carbonate, and that the minium might be replaced by pure litharge, or protoxide of lead. In point of fact, the small quantity of saltpetre which is usually added, exerts a beneficial effect, by increasing the proportion of oxygen, and assisting to drive off the globules of air in the liquid glass. This salt, when the price admits of its application, is at once a pure and a purifying material. A few ounces of manganese are employed to neutralize the greenish tint produced by the presence of iron or other impurities; and, with this view, the peroxide must be used in the purest crystallized state.

Melting and Fining of Flint-Glass.—The plan and sectional elevations of a melting furnace, figured at pages 199 and 200, are equally applicable to flint-glass, and other descriptions of glass, except that for bottle and crown-glass the furnaces are usually oblong, and are only constructed to contain from four to six pots; whereas, for flint-glass works, round furnaces, containing from eight to twelve pots, are almost exclusively used. Mr. APSLEY PELLATT remarks, that ten pots of thirty-six inches diameter are the medium number for a well-proportioned furnace, and are found the most economical for fuel. When the furnace has too large dimensions, too great an area is left unoccupied by the pots or fuel, and too small a furnace exposes the backs

Fig. 172.



of the pots to hang over the fire-place in the centre, which in time enlarges by burning away, and causes the pots to crack at the bottom, or back, by cold draughts through the fire-bars. According to the same authority, a furnace of twelve pots, exposing a much larger unoccupied area than a ten-pot furnace, will consume nearly double the quantity of fuel in uselessly heating the interior, whereas twelve pots of melted metal will hold only in the proportion of one-fifth increase. On the other hand, furnaces of less dimensions than eight pots are objectionable, through the great loss of pots, in consequence of the comparatively small size of the siege. In the Falcon glass-house, belonging to Mr. Pellatt—and from which have emanated many important improvements—there are two furnaces, instead of one, both opening into the same flue, as represented in Fig. 172, which shows also an interior view of the glass-house and working operations. By this arrangement, while one of the furnaces is in full operation the other may be undergoing repair, or the working of one may be entirely suspended without injury to the other, during a dullness of trade.

But the principal and only essential difference in the conditions for the melting and fining of flint-glass, consists in the shape of the pots, which, as represented in Fig. 142, page 201, are distinguished from those employed for other descriptions of glass, by being covered with a hood-shaped top, the mouth of which fits the working holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass furnaces. Open pots are used in some parts of France for flint-glass, with dried beech or oak-wood for fuel, and so little carbon is produced by the smoke as not to affect materially the metal, although the flames play upon its surface; but when coal or coke is used, as in this country, the fumes and smoke emitted would carbonize or deoxidize the lead, and precipitate it to the bottom in the original metallic state, if the pots were not covered; besides that the solid particles of soot would blacken the glass, by attaching themselves firmly to its surface.

The ingredients previously mentioned, having been carefully mixed together and sifted, are brought to the furnace in wooden vessels, like hand-barrows, and thrown into the pots in successive charges with an iron shovel. In this state the batch or frit, as the composition is called, is of a salmon color, the red tinge being derived from the oxide of lead. English melting-pots, which are usually much larger than the French, hold about eighteen hundredweight each, and the batch is introduced in quantities of about four hundredweight at a time, allowing a sufficient interval between each filling for melting down the various charges, until the pot is entirely filled with fused glass. By this method, says Mr. Pellatt, every pit in the furnace is fully charged with liquid metal in about twelve to fifteen hours; air-bubbles and striæ then abound, and they are not expelled until thirty to forty hours more have elapsed, during which period—namely, from fifty to sixty hours—the gas and air-bubbles are driven off, and the mass becomes homogeneous. During the founding, the mouths are securely stoppered and clayed up, and the furnace is urged to its utmost intensity. The shorter the time of fusion and refining, the better; for this purpose the heat can scarcely be too great. With the best possible recipe, and the purest materials, good results depend upon an intense and continuous fusion. too little caloric will fail to refine the metal and drive off air-bubbles, and the coloring matter of the manganese; and too long continuance of intense heat will destroy the manganese, cause the glass to attack the pot, and become striated, gelatinous, and greenish. If the glass do not get fine by the usual time allotted, but becomes coddled or gelatinous, it never will recover, however urged by subsequent fusion. Such glass may be ladled into water, and considered only as cullet for re-fusion, with a proportion of new materials. The moment the metal is fully fused, and refined by continuous rapid fusion, the high temperature of the furnace should be reduced from its maximum heat to a working temperature; this period being considered *the crisis.* When flint-glass is kept in fusion beyond the crisis, it not only assumes a greenish tint by acting upon the iron of the Stourbridge clay-pot, but takes up a small portion of its alumina, which, by its inferior density, rises to the surface, frequently with detached portions of the pot, causing striæ and other impurities which injure its quality for common uses, and render it entirely unfit for optical purposes. Formerly, scum or sandiver was allowed to run off, or was skimmed from the surface of the pots when opened for working, but the modern relative proportions and purity of the chemical materials are so good, as seldom to render this skimming necessary.—*Pellatt.*

Mechanical Operations.—The mechanical operations connected with common bottle glass, crown, sheet, and plate-glass, are uniform in their character; the description of the making of one bottle, or of one table, sheet, or plate of glass, applies to all. On the contrary, the infinite variety of shapes into which common flint-glass or crystal is manufactured, would render a complete account of the manipulations tedious, even if it were not in some degree foreign to the plan of this work. Only a few examples will, therefore, be selected, to illustrate the general character of these ingenious processes.

Flint-glass is either formed by simple blowing with the pipe, and then shaping by hand; or, secondly, by blowing in moulds; or, thirdly, by moulds alone, in which the glass is subjected to pressure. In each of these cases, the form and appearance of the article are very generally improved by grinding, cutting, *et cetera.*

Fig. 173.

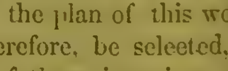
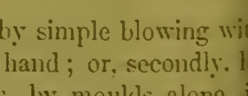
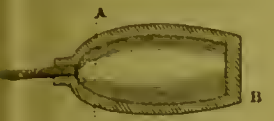


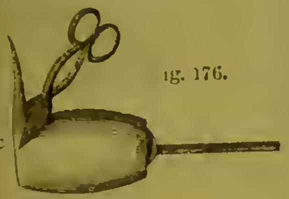
Fig. 174.



By way of illustration, the common tumbler may be mentioned as one of the simplest articles to make by hand. In this case the workman collects on the end of the pipe a small quantity of glass—Fig. 173; this is rounded on the marver, expanded by blowing, and somewhat elongated by swinging, when it assumes the form—Fig. 174. The pipe is then suspended vertically, and the glass is allowed to drop by its own weight upon the marver, which flattens it at the extremity; and, being at the same time further blown, it now resembles—Fig. 175. The pipe, with a portion of the glass, is then detached, by touching the piece with the cold pucellas at A; this contracts and slightly fractures the glass, which is, subsequently, cracked through the entire circumference by a smart blow of the same instrument. In the meantime, the ponty has been attached by adhesion to the flat end, B, and the other end, which now corresponds to the dotted line, is first expanded with the pucellas, and then sheared as at C—Fig. 176—so as to make it perfectly even, as at F—Fig. 177—and fit it for the flashing and finishing. Finally, it is knocked off from the ponty by a sharp blow, and taken to the annealing arch.

Fig. 175.





ig. 176.

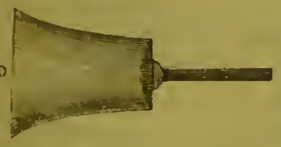


Fig. 177.

Part of the above process is omitted for common light cheap tumblers; these are not sheared, but simply flashed, and no pains is taken in subsequently polishing out the marver marks. Hence they are often ringy or wavy.

Wine-glasses are usually made in three pieces. The process is the same as for the tumbler, till the gathering assumes the shape represented in Fig. 175. A solid ball of glass is then attached to the flat end, as in Fig. 178, this being a separate gathering, out of which the stem is shaped by the pucellas, while it is rotated on the inclined planes of the glass-maker's chair. It then assumes the form represented in Fig. 179. To form the foot, a small hollow globe is now attached to the stem, which is afterwards opened by the pucellas, as in Fig. 180; and when the pipe, with a portion of the glass, is separated from the other end, and the mouth expanded, sheared, and flashed, the glass finally assumes the form represented in Fig. 181.

Fig. 178.

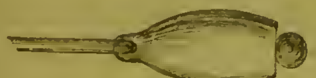


Fig. 179.

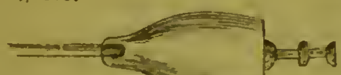


Fig. 180.

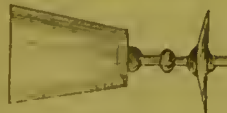


Fig. 181.

To make a ringed decanter, the glass, by the process already described, is brought to the form represented in Fig. 182. The ponty is then attached to the flat end, and the mouth is warmed up, and shaped with the pucellas, as in Fig. 183. Another workman then gathers upon a ponty a small piece of glass, which is dropped on near the mouth, as shown in the same figure, and, by rotating the decanter, the entire circle or ring is welded by contact, and its surplus tapered and torn suddenly off. By re-heating the decanter, a second, third, and fourth ring may be added, as shown in Fig. 184.

Fig. 182.

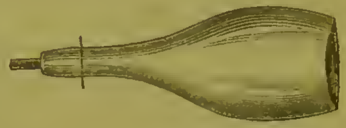
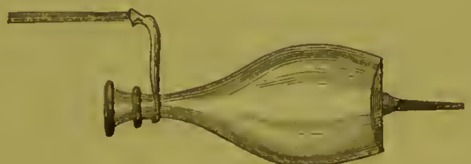
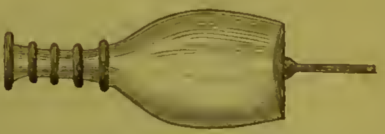


Fig. 183.



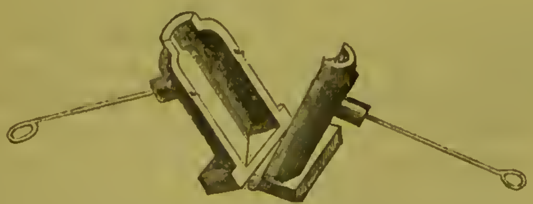
The process of blowing and moulding common green glass bottles has been briefly described at page 210. Bottles and other articles of flint-glass are blown and moulded in much the same manner, but the finer descriptions are afterwards cut and ground. Moulded glass never exhibits a full lustre, nor even the sharpness of the metallic mould. The glass, not being perfectly liquid, does not penetrate into the sharp corners, nor does it even accommodate itself perfectly to the flat sides of the mould. Hence the edges are blunt, and the surface is never perfectly even, but more or less curved and wavy. Moulded articles can, therefore, never be compared with cut-glass, but some are now produced of remarkable beauty; and even as a preparatory step to grinding, the use of moulds is of great advantage, as the vessel acquires a regular form, and presents, although in a crude state, all the prominent and receding features, to be perfected at the lathe.

Fig. 184.



The moulds for flint-glass are carefully constructed of brass or iron, and, when of simple construction, are somewhat wider at the upper part, that the pieces may be easily removed, or are composed of more than one piece when projecting parts are to be moulded. A common *open and shut mould*, such as is used for apothecaries' phials, as well as for common wine-bottles, is shown in Fig. 185. It is constructed in two exact halves, connected with a bottom hinge. The glass to be moulded is gathered on the pipe, rolled on the marver into a cylindrical form, and then pinched with

Fig. 185.



the pucellas at the end attached to the pipe, to form the neck of the bottle. The cylindrical mass, still adhering to the pipe, is then inserted into the mould lying on the ground; its two halves are shut; and the workman blows through the tube, which renders the mass of glass hollow, while it receives from the mould the external form required. With this form of mould two seams or lines are produced, by the two sides of the mould not shutting quite closely. In round bottles these seams are unsightly, but they are scarcely perceptible in square bottles, as the joinings of the mould are placed at two of the corners.

This imperfection, though not entirely removed, is much diminished by the use of an improved mould, invented by Mr. PELLATT, and represented in Fig. 186. It consists of one piece, D, for the body, and two pieces, B B, for the neck. By this construction the seam down the body, so objectionable in round bottles, is avoided, although the neck is still marked by two slight seams. The neck-pieces, which are kept open by a spring, C, are brought together, after the insertion of the globe or spheroid of metal, by the guide, E, on pressing down the treadle, F, with the foot. The workman then blows through the pipes, and, on raising his foot, the counterweight, A, falls, and the bottle is readily taken out.

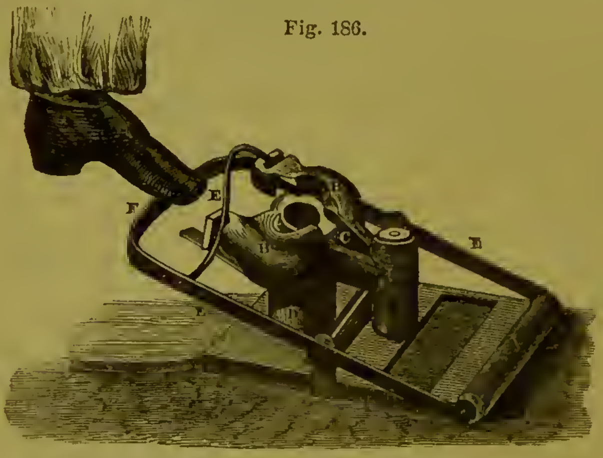
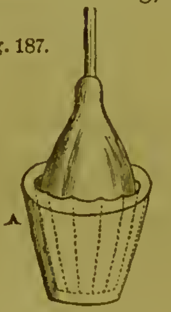


Fig. 186.

Moulded Roman Pillars.—With reference to this species of moulding, recently introduced by the English manufacturers, Mr. PELLATT remarks that it owes its refractive and cut-like effect to its inequalities of substance, the interior having no indentations to correspond with its exterior projections. In this case the mould is only about one-third the size of the object to be manufactured. The metal is first gathered upon a pipe in the ordinary manner, except that the first gathering is allowed to cool more than usual, and the second coating is pressed into the mould, A—Fig. 187—as hot as possible, so that only the exterior portion may be acted on by the mould, while the interior preserves its smooth circular section. When about half-formed, the projecting parts, B—Fig. 188—have a centrifugal enlargement given to them by a sharp trundling of the iron at, or immediately after the blowing. During the re-heating process, the piece is separated at the dotted line, C, has a foot welded to it, and is re-warmed as D—Fig. 189. It is then sheared, as E—Fig. 190; and when finished by flashing, shaping, *et cetera*, so as to appear as in Fig. 191, it is known as patent pillar moulding. A little cutting or scolloping makes this refractive moulding still more ornamental; but though it much resembles cutting, as to its round pillars, it is inferior where sharp angles are required. Pillar moulding is, however, one of the greatest modern improvements, and is used advantageously for lamp-pedestals, chandelier work, toilet-bottles, salt-cellars, *et cetera*, at very moderate cost.—*Pellatt.*

Fig. 187.


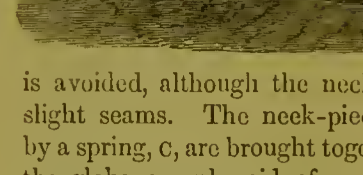


Fig. 188.

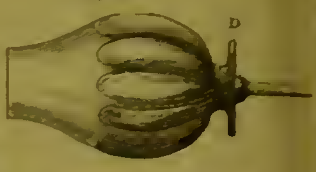
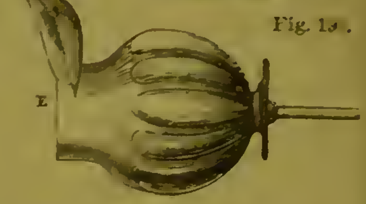
Fig. 189.


Fig. 190.


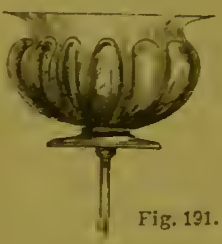
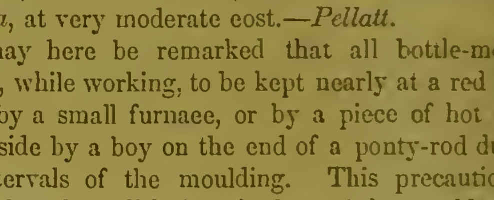


Fig. 191.

It may here be remarked that all bottle-moulds require, while working, to be kept nearly at a red heat, either by a small furnace, or by a piece of hot glass held inside by a boy on the end of a ponty-rod during the intervals of the moulding. This precaution is essential to the polish, but the heat of the moulds must be kept below redness, otherwise the glass would adhere to them.

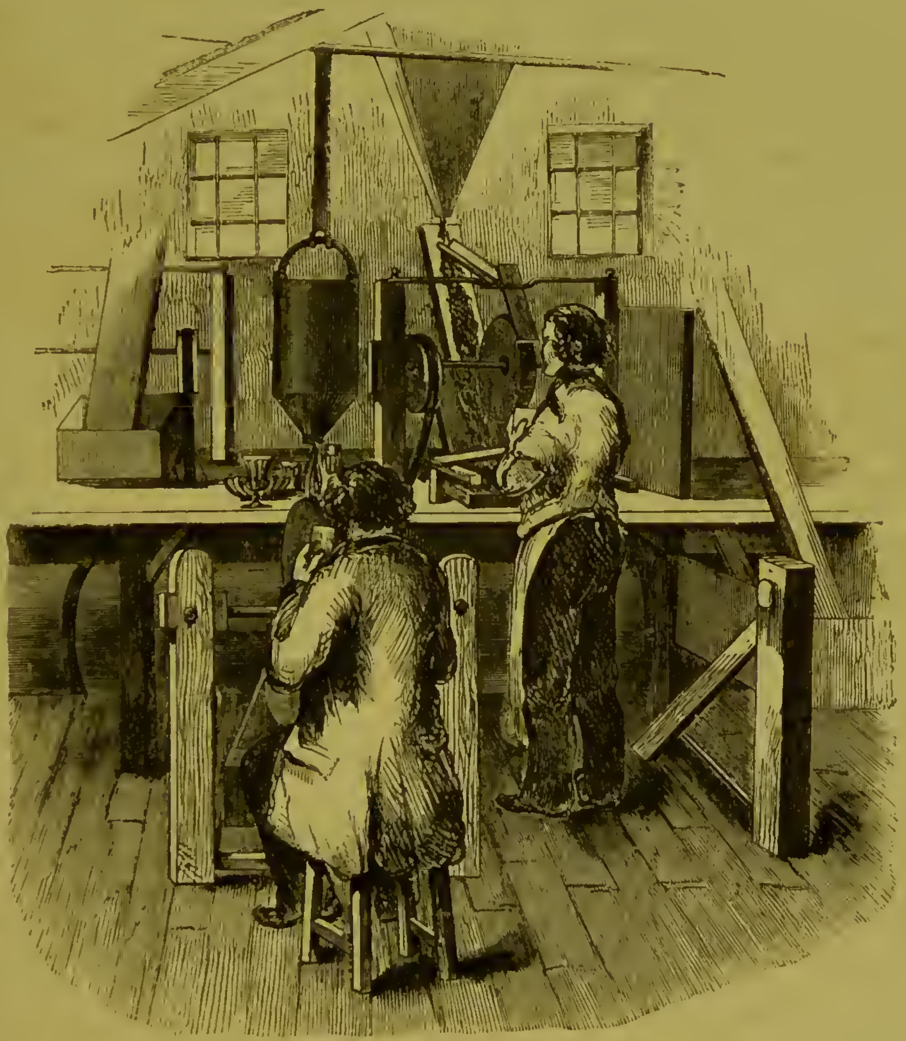
Pressing.—The third method of manipulation with flint-glass, is moulding by pressure—an American invention, which consists in dropping the soft metal into a prepared die, and then pressing down the matrix or plunger upon it by means of a lever. The chief conditions of success in this operation are, to take care that sufficient glass is introduced to fill the mould, and that the latter is kept at a steady temperature, a little short of red heat, to produce a polished surface. When the die or mould is once formed, articles are produced in this way with great rapidity; but much practice and dexterity are required to gather the exact quantity of metal. Under this head may be mentioned drop-pinching, or the moulding of drops for chandeliers, girandoles, and candlesticks. In this case, lumps of glass made expressly for the purpose, are first softened by a blast-furnace, and then shaped in twin-dies, A B—Fig. 192. Arms of chandeliers are formed

Fig. 192.


on the same principle, but using a powerful leverage press. Both arms and drops are afterwards cut and polished, to produce the required brilliancy.

Cutting and Polishing.—The finishing process which gives to the finer articles manufactured of flint-glass their distinguishing beauty, is technically termed *cutting*, but is actually performed by grinding. The inferior hardness of flint-glass renders it fitter for this purpose than any other glass. The operation, as represented in Fig. 193, is performed by discs of iron, sandstone, or copper, revolving in a lathe which is usually propelled by steam power. The edges of the discs, which are sharp, angular, or rounded, according to the work to be performed, are supplied with sand and water dropping from a hopper for *rough grinding*, and with emery for *fine grinding.* A stone-wheel with water is employed to smooth out the rough sand-marks, and prepares the glass for the *polishing*, which is effected by means of a willow-wood disc, first with a mixture of pumice and rotten-stone, and finishing with a preparation of tin and lead, termed putty-powder. All table-glass ware and hollow articles are thus cut.

Fig. 193.



Chandelier drops are cut or ground with iron and stone-wheels in the same manner, but are finished with a lead-wheel supplied with a little very fine rotten-stone and water.

For many years the practice has been introduced of roughing lamp-lustres by means of sand. It is easy to conceive how the exterior roughing may be performed, but the rubbing of the interior surface appears a more difficult operation. It is, in fact, performed on a somewhat different principle. In this case, sand of a uniform grain is put into the globe or lustre; a certain number of these globes are arranged in a drum or cylinder, and a rapid rotatory movement is given to the latter, by means of which the interior surfaces of all the globes are quickly worn and roughed in a very equal manner.

Glass-Engraving.—Small copper discs of the size of a halfpenny, and finely pulverized emery mixed with oil, are used to execute the outline and ground of the glass-engraver's work; and for polishing, lead-wheels and very finely pulverized emery are employed. Coarse patterns for hall-lamps are engraved by the glass-cutter's smoothing wheel; and Mr. Pellatt remarks that the contrast of the polish of a wood-wheel upon a ground roughed by sand is often effective, though the range of pattern is somewhat curtailed by the large size of the cutter's ordinary wheels rendering it difficult to execute curvilinear designs. For inscribing initials, coats of arms, and minute designs, very small discs must be employed. The finest incisions are made with copper pencils, either pointed, or ending in a button-like disc.

Etching on Glass.—It has been stated at page 199, that hydrofluoric acid, either in the gaseous or liquid state, exerts a peculiar action on glass, which has been turned to account as a substitute for cutting or engraving designs; and though not confined in its application to flint-glass, the process may be appropriately described in this place.

For etching on glass by means of the gaseous acid, the glass is cleaned, well dried, heated, and melted varnish poured upon it, which is spread in a homogeneous coating. This varnish is formed of wax and turpentine; it ought to be soft enough to admit of being removed by the burin without scaling it off; it is generally formed of one part of turpentine to four parts of wax. When the glass is cold, the varnish acquires a little opacity, but not so much as to prevent tracing through it. The burin is then passed over the varnish, following the lines of the figure, and cutting through the varnish to the glass. When the figure is traced, the glass so prepared is exposed to the action of hydrofluoric acid. For this purpose a leaden tray or earthen vessel is used; in this is put fluoride of calcium pulverized with concentrated sulphuric acid; it is mixed well, and the vessel is then placed on a very gentle fire, and the glass to be etched is laid over it. At the end of some minutes from the time when the vapor begins to rise, the operation is terminated; the glass is then taken off, and the varnish is removed by melting it, and wiping with a soft linen rag.

If, instead of exposing the glass to the action of the acid vapors, it is plunged into the weak liquid acid, the same effect is produced in a few moments.

But when it is desired to produce a very pure and correct figure, with half-tints and strong shades, recourse must be had to a longer and more delicate process; a particular varnish, too, must bo used.

The best is drying linseed oil, or, better still, fat varnish of copal blackened with lamp black, perfectly pulverized, and sprinkled with oil of turpentine. The coatings laid on must be very thin, and each should be quite dry before putting on a new one. The glass is sufficiently covered with varnish when the light can scarcely be seen to pass through it. The design is then copied through, and the varnish is removed from the lines with the points of gravers, or simple needles of different forms and sizes. For greater convenience, the design is lighted from below by inclining it at an angle of about 45° on a desk pierced for a window. The position of the glass enables one to perceive the most delicate lines.

After having formed the figure, it must be corroded out with liquid hydrofluoric acid; but before commencing this operation, it is necessary to test the glass as well as the acid. This preliminary trial is made on a small piece of the same glass, covered with tho same varnish. This piece is divided into five or six parts; on each of these parts some traces are drawn with tho needle, and the operator covers them successively by means of a pencil with liquid hydrofluoric acid. A minute is allowed to intervene between each operation, so that when the acid has acted during one minute on the last portion, it has then been in contact with the glass for two minutes on the preceding one, and for six minutes on the first. This being done, the slip of glass is washed with plenty of water, and the varnish is removed by means of a knife and spirits of turpentine. It is then easy to determine the proper time for allowing the acid to act upon the design to be etched.

BEDFORD patented a peculiar process for etching glass, which consists in grinding five parts of peroxide of lead and one part of flux, composed of seventeen parts glass of borax, and thirteen parts of red lead, fused together. The peroxide of lead employed is puce-colored, and with the above composition the artist paints the devices or designs upon the surface of the glass. When the etching is to be done on colored glass, acetate of lead is substituted for the oxide. The article is then dried, and fixed in the same manner as in gilding glass. When cold, it is dipped in a weak solution of nitric acid, and as soon as the painted designs are acted on, it is placed in water, and the preparation removed from its surface.

On the whole, it must be admitted that etching by fluoric acid, though practised to some extent, and in some particular cases with marked success, has not been found effective for general purposes. It is usefully applied, however, to form the scales on thermometer tubes, and written or printed inscriptions on glass vessels. The attempt to make it subservient to typographical purposes has been a failure.

OPTICAL GLASS.—There are two kinds of optical glass—flint and crown—which, having different refractive and dispersive powers, may be so combined in the object-glass of a telescope that, while the rays are brought to a focus, the greater dispersion of the flint lens may be corrected by the less dispersive power of the crown—the one being negative, the other positive. Hence, by their combination, the lenses achromatise each other, or transmit colorless light. The celebrated DOLLOND, in 1753, aided by the co-operation of EULER, and of KLINGENSTIERNA the Swedish mathematician, succeeded, after many experiments, in discovering the due proportions of the curvatures of the two lenses; but still two important problems remained to be solved—the best chemical constitution of the glasses, and how to obtain them sufficiently free from the defects of ordinary glass to be adapted for optical instruments. It is this last question which presents the greatest difficulty. Purity, unchangeableness of color, transparency, and a certain degree of refractive power, may be obtained; but perfect uniformity in the structure of the glass, so as to render its composition absolutely homogeneous throughout, is much more difficult to be accomplished: and this is precisely the quality which is admitted to be the most indispensable for good optical glass. The difficulty arises chiefly from the difference in specific gravity of the different constituents of the metal. Some melt at a lower temperature than others; some evaporate or are decomposed in a heat required for the fusion of others; and different substances cool at different temperatures. Hence arise discoloration, threads, striæ, irregular crystallization, causing irregular refraction, and all the usual faults observable, more or less, in every description of glass.

It seems to be now generally admitted that there are more impediments in fabricating crown-glass lenses of large size, than in making good ones of crystal or flint-glass. The former requires a higher temperature, and by adding alkali to increase the facility of fusion, it becomes more liable to attract humidity, or, as it is technically termed, to sweat. On the other hand, by rendering it too hard, one incurs the risk of crystallization and imperfect vitrification in cooling.

For a long period, however, the principal attention of opticians and glass-makers was devoted to the manufacture of a suitable flint-glass, which was considered to present the greater difficulty of the two. Occasionally, the flint-glass manufacturers found in their pots a portion of glass suitable for opticians; but this was an accidental product. The problem of the constant and regular manufacture of good optical flint-glass still remained to be solved, when M. Guinand, a workman in the clock and watch trade, near Neufchatel, who had been accustomed to the fusing of metals in the prosecution of his business, devoted his attention to the subject, and succeeded in producing masses of flint-glass capable of furnishing objectives of nine inches—a size previously unknown. Even the celebrated chemists, Macquer Roux of St. Gobain, and Auut of Langres, had never been able to obtain them of larger diameter than three to three and a half inches. M. Dartigues also, one of the first manufacturers of flint-glass in France, and who to his high reputation for practical skill added that of scientific knowledge, equally failed of success. Guinand's discovery was therefore hailed with much satisfaction; but he kept the process a secret, except from M. Utzschneider and the celebrated M. Frauenhoffer, who proposed to him to join them in their establishment at Munich. This offer Guinand accepted, and the process was successfully worked by them for several years without any one being able to discover it. After their deaths, one of Guinand's sons being in possession of his father's method, continued the manufacture of optical glass in the environs of Neufchatel. The other son formed an association with M. Bontemps, one of the directors of the glass-work of Choisy-le-Roi, but the experiments which were made by them conjointly at that establishment did not succeed. The treaty was therefore broken; but M. Bontemps and his co-director, M. Thibeaudeau, satisfied of the correctness of the principle, if properly applied, continued their experiments without excluding Guinand; and ultimately, in 1828, they succeeded in producing good optical glass in discs of from twelve to fourteen inches, and a large quantity of smaller sizes. From that time the manufacture has been established on a regular system. In 1848, M. Bontemps was induced, in consequence of difficulties arising from the political state of the country, to retire from his position at Choisy-le-Roi, and to accept the invitation of Messrs. Chance, Brothers, and Company, to unite with them in attempting to improve the quality of this important branch of manufacture. How far they have succeeded may be judged of from the fact, *that they have produced discs of flint-glass twenty-nine inches in diameter, weighing two hundredweight, and of crown-glass up to twenty inches.* These discs are pure in color, good in structure, and exempt from those defects which tend to polarization of light. Bontemps' proportions for optical glass are as follow:—

FOR FLINT-GLASS.

Sand,	43·5
Red lead,	43·5
Carbonate of potassa,	10·0
Nitrate of potassa,	3·0
	100·0

FOR CROWN-GLASS.

Sand,	60
Carbonate of soda,	25
Carbonate of lime,	14
Arsenic,	1
	100

It will be observed that optical flint-glass is chiefly distinguished by the large proportion of lead which enters into its composition. According to Dumas, who approached very near to the truth in assigning its probable composition, its density should not be lower than 3·6 at least. The essential point in the manufacture, however, consists in the constant stirring of the metal during the melting and fusing. The superiority of Guinand's plan is considered not to have been in the novelty of the materials or proportions, but in carefully agitating the liquid glass while at the highest point of fusion, *then cooling down the entire contents of the pot in a mass*, and, when annealed and cool, separating unstriated portions by cleavage. It is worthy of remark, that some time before Guinand's death, a commission of the Astronomical Society of London, composed of Messrs. Herschel, Faraday, Dollond, and Roget, having been instructed to conduct an inquiry into the manufacture of flint-glass for optical purposes, arrived at the result that the necessary improvement was chiefly mechanical, not chemical, and that freedom from striæ could only be obtained by a constant agitation of the mixture. Faraday, who took the lead in the inquiry, both in his own laboratory and at the glass-works of Messrs. Pellatt, changed, however, the composition, as well as the principle of fabrication, and produced a borate of lead of remarkable purity. This substance, known as Faraday's heavy glass, which has proved so important in experiments connected with the polarization of light by magnetic action, is composed of the following ingredients:—

Protoxide of lead,	104
Silicate of lead,	24
Dry boracic acid,	25

This glass required but a red heat for fusion, thereby, as Mr. Pellatt remarks, offering facilities for minute agitating operations. It was found, however, not to be durable, and therefore not calculated for application to optical purposes or general use. The common process for making optical glass is described by Mr. Pellatt as follows:—A ladle, in the form of a sugar-loaf, about five inches in diameter and seven inches deep, is dipped carefully into the metal, which has been previously skimmed; when filled, it is taken out of the pot, and suffered to get partially cool. To the large end of the sugar-loaf-shaped piece of glass thus produced, a glass-blowing iron with a hollow disc is welded, and placed to the opening or mouth of the pot for reheating; when sufficiently soft, it is blown into a muff; the end furthest from the blowing-iron is cut off, the cylinder is flattened into pieces or plates of fourteen inches long, ten inches wide, and about half an inch thick, and annealed; in which state the plates are sold to the optician for cutting and grinding into discs.

Zinc Optical Glass.—Allusion has already been made to a new kind of glass which was sent to the Great Exhibition of 1851 by M. Maës of France, and was honored with a Council medal, as an instance of novelty of chemical application in the manufacture of optical and other descriptions of glass. The basis of this vitreous compound was oxide of zinc—a certain quantity of borax or boracic acid being added, to give the glossy character for which the boracic compounds, no less than the silica, are so eminently remarkable, combined with an easier fusibility. Its extreme limpidity, and total freedom from color, veins, and striæ, appeared to the council jury eminently to fit it for telescopes, prisms, and other optical apparatus—as a substitute, however, not for the flint-glass, but for the crown, in achromatic telescopes., The low dispersive power of the zinc compounds points to the use of glass of zinc for this purpose. Its refractive index is 3·285, and its dispersive ratio, as compared with a flint-glass of specific gravity 3·55, is as 0·6502 to unity. With reference to this peculiar glass, the following passage occurs in the Report of the Council Jury on Optical Glasses:—Suppose it should be found practicable—and the experiment is recommended to the attention of artists, as one in which, when tried on a very small scale, some success has actually been obtained—to form colorless and uniform glasses, in which fluorine enters as a distinguishing ingredient, in combination with silica, alumina, or other materials; the combination of such glass, as a convex lens, with this new material of M. Maës, or with ordinary crown-glass as a concave, might be expected to produce achromatic object-glasses of a very perfect description. The colored dispersion to be removed being much less than that of crown-glass, owing to the peculiarity of the fluoric compounds which beset the manufacture of flint-glass, arising from the intense solvent power of the oxide of lead on the crucibles, and give rise to striæ and veins, would be evaded. M. Maës, besides two prisms of his new glass, of the most limpid purity, and perfect freedom from veins or striæ, exhibited two discs of four and a half and seven inches in diameter, prepared for optical use. In an examination, through faces cut on their edges, no veins or striæ were detected, and, consequently, should there arise no objection to this material, either in point of durability or facility of working, it will probably prove very valuable for the use of the optician.

VI. Strass and Colored Glass.—The manufacture of glasses tinged, colored, or stained, by different processes, has now become a business of great and growing importance. The taste for stained-glass windows, which formed so distinguished a feature in the history of a former period, has revived, and is now displayed in the decoration, not only of splendid palatial and ecclesiastical structures, but even of many private dwellings; the skill of the Venetians of a former day, in producing colored vases and other ornamental articles of glass of every variety of hue, is equalled if not surpassed in modern times; and artificial gems, or pastes, which are true glasses, are now formed, that emulate, if they do not eclipse, in sparkling lustre and pure transparency, the rarest and most beautiful natural productions of the mineral kingdom.

Although all the varieties of glass can be colored at pleasure by virtue of the property possessed by the greater number of the heavy metallic oxides of producing colored compounds with silica, yet in individual cases it depends upon the object in view, and even on the nature of the color, whether a glass void of lead, or a lead-glass with its higher refractive power, is employed as the basis for the coloring material. In general, however, the basis of the color, or that with which the coloring matter is actually mixed, is a lead-glass, and this, when real *glass-painting* is the object, is applied either as a pigment or in a melted state on common glass or some other finished article; in other cases, the colored lead-glass is itself formed, cut, or moulded into the finished article. When the latter is an artificial gem or paste, a peculiar glass is employed, termed *strass*, which it may be proper to describe in this place, before proceeding to give a short account of the different coloring materials, and the different methods of their application in particular cases.

Strass, so called from the name of its inventor, constitutes the only true glass not yet described, and forms, as above stated, the basis of artificial imitations of precious stones. For this purpose a glass is required, possessing the highest degree of purity and transparency, combined with the greatest possible lustre. These requirements are found in a composition analogous to that of flint-glass, but containing a much larger proportion of oxide of lead and a little boracic acid. Donault-Wieland recommended, by way of example, either of the three following mixtures:—

	No 1.	No. 2.	No. 3.
Ground rock-crystal,	100	—	100
Sand,	—	100	—
Pure minium,	156	—	154
White-lead,	—	171	—
Purified caustic potassa,	54	32	56
Boracic acid,	7	9	6
Arsenious acid,	.3	·3	·16

From these proportions, and from the analysis of a strass manufactured by Donault-Wieland, which was given at page 192, it will be seen, that not only does the oxide of lead greatly exceed in amount that which is contained in crystal or common flint-glass, but that it is present in larger proportion than even in optical flint-glass. This will be observed by glancing at the same table in the page above-referred to, where flint-glass from Guinand, or, in other words, optical glass, is placed in juxtaposition with strass and enamel. The very large proportion of oxide constitutes, in fact, the distinguishing peculiarity of the former, while the latter is further distinguished by containing oxide of tin, or is in reality a strass with a mixture of oxide of tin or stannic acid.

Strass, when well prepared, possesses as nearly as possible the high refractive power and all the other properties of the diamond, except its hardness. When cut into shape, therefore, without the addition of any coloring matter to its composition, it answers for imitating the diamond. On the contrary, when tinged by silicates with metallic bases, it furnishes imitations of all the colored stones. For this purpose its perfect purity and high lustre are essential requisites. It is necessary, therefore, to exercise great care in the choice of the materials. The rock-crystal, quartz, or sand employed, must be of the purest description. The last two always contain a little iron, which colors the glass yellow, and should therefore be washed with hydrochloric acid after being carefully pulverized. The potassa must not be mixed with any other salts. DONAULT-WIELAND preferred the finest caustic potassa; but DUMAS remarks that the use of the nitrate might be preferable on account of the constant purity of that salt. The borax of commerce—that of Holland, for example—would produce a brown glass; crystallized boracic acid is therefore preferred. The oxide of lead employed is very pure minium.

DUMAS remarks that the choice of the crucibles is very important, and that the Hessian ones are better than those of porcelain. The crucibles sometimes color the metal yellow or brown, when particles of iron are detached from the internal surface. This inconvenience is not to be apprehended with crucibles of hard porcelain, but these often break or run out, and are too permeable. A pottery or porcelain furnace is used to melt the material, and the crucibles remain in the fire about twenty-four hours. The more tranquil and prolonged the fusion, the greater hardness and beauty does the strass acquire. If the crucibles are of excellent quality, a porcelain furnace may be used; but when the loss occurring is too great, one must be contented with a common potter's furnace.

COLORING MATERIALS.—It has been stated that colorless strass is the basis of artificial gems, most of which are formed by mixing with the strass certain coloring materials. In the article ENAMELS, many of the substances employed for this purpose have been enumerated; but further details may now be given in connection with the general subject of *colored glass*, before proceeding to the special proportions employed for imitating certain precious stones.

Yellow is produced either by charcoal, antimony, silver, or oxide of uranium. The charcoal, incorporated with the glass in a very fine state of division, produces a dirty yellow, which, as the quantity increases, passes into a dark brown without lustre; it is, therefore, little used as a pigment. A much superior yellow is obtained by roasting sulphide of antimony to the state of antimonious acid, and melting it with from 3 to 5 per cent. of undecomposed sulphide of antimony. An *orange yellow* is prepared with glass of antimony, minium, and a little oxide of iron. In these cases, the substances so prepared are mixed with the materials of the glass. When silver is employed, the process is quite different; in this case a mixture of powdered clay and chloride of silver is applied to the surface of the ready-made articles, and on reheating these in a muffle, the silver penetrates to a certain depth into the glass even before the latter softens; the article is then allowed to cool, and the coating which was applied is scraped off, when a yellow color of great purity and brilliancy appears on the glass. It is remarkable that this effect can only be produced on glass containing alumina, which shows that the action is chemical, and not purely mechanical. Oxide of uranium produces a beautifully delicate yellow of a slightly greenish hue, which is attributed to the traces of iron usually found in the commercial oxide; but this pigment is too costly for common use.

Red, of different shades, is communicated by oxide of iron, suboxide of copper, or different preparations of gold, mixed with other materials. The oxide of iron —F_2O_3—is employed either as pure oxide, prepared by heating the nitrate, or in the state of bloodstone or ochre. This substance, added to the glass mixture, produces a cheap and very common brownish red. The peculiar action of suboxide of copper has already been explained under ENAMELS, vol. i. page 821. This substance was much employed by the artists of the fifteenth and sixteenth centuries, for producing the brilliant red colors of window panes, and in later times the glass so colored was supposed to be indebted to gold for its beautiful rich hue. So intense is the coloring power of this oxide, that even a very small quantity reddens the glass so much as to render it opaque, and hence it is almost impossible to command any desired tint in applying it. Even a common window pane is scarcely permeable to the light when coloured with a small portion of this substance; and hence in crystal vessels, which are necessarily of much greater thickness, especially when intended for grinding, the effect becomes excessive—the glass is rendered quite opaque. To obviate this difficulty, recourse is had to the process of *flashing* or coating white with colored glass, as will be explained afterwards—a process so successful that it was subsequently extended to other colors.

The application of gold to produce a brilliant red color, which, according to circumstances, can be made to assume a scarlet, carmine, rose, or ruby tint, was first introduced by KUNKEL, who used for the purpose the brownish-red precipitate produced in a solution of chloride of gold by a salt of the sesquioxide of tin. This substance, known as the purple of CASSIUS, was long believed to be the only preparation of gold which could be employed for this purpose, till FUSS demonstrated that ruby-colored glass may be obtained when the powdered ingredients for the glass are mixed, previous to fusion, with oxide of tin and the solution of gold; the mixture then appears like moist grey sand. Experience has further shown that the simple addition of a solution of gold to the flux, without any oxide of tin, is capable of producing rose and carmine-colored glass.

Blue is produced by oxide of cobalt, a pigment which is equally applicable to lead-glass and to glass containing no lead, but in the latter the color is more intense. The coloring power of the oxide of cobalt is so intense, that pure white glass is rendered sensibly blue by the addition of one-thousandth part of the oxide. Ample information as to the methods of preparing blue cobalt glass, which is produced in a pulverized state as a pigment, under the name of *smalt* or *zaffre*, has been given in the article COBALT.

Green may be produced either by protoxide of iron, protoxide of copper—CuO—or oxide of chromium—Cr_2O_3. The tint produced by the first of these substances has little brilliancy. The oxide of copper yields a beautiful emerald. For this purpose the glass is mixed with the product obtained by heating copper to redness with access of air, or with powdered verdigris, which is then decomposed in the fire, and converted into oxide by oxidizing agents. Care must be taken to prevent the protoxide of iron from being converted into sesquioxide, and the oxide of copper from being reduced to suboxide. The oxide of chromium, which occurs as a pigment in commerce, yields the purest and most brilliant grass-green hue, but is too costly for common use.

Artificial Gems.—The preceding cases may be sufficient to illustrate the general character of the substances employed to tinge glass, whether in the fabrication of artificial gems, or in the more important art of enriching with color articles of common use or ornament. Before proceeding to this latter subject, which embraces different methods of applying the coloring material, the following may be given as the most approved recipes for imitating those precious stones that are deemed of highest value:—

Diamond.—Colorless strass, without any addition.

Topaz.—Donault recommends the following mixture:—

Very white strass,	1000
Clear yellowish orange-red glass of antimony,	40
Purple of Cassius,	1

A very good imitation of topaz is obtained from—

Strass,	1000
Oxide of iron,	10

Topaz, when obtained by the first of these two compositions is very subject to vary in tint during the fusion, according to the temperature and the time it is exposed to the fire. It passes from the colorless strass-white to a sulphur-yellow, violet, and reddish purple, according to circumstances, which are not well understood. This substance may be compared to the *rubin-glass* of the Germans and Italians. The glass of antimony must be selected of the greatest transparency, and of a clear orange-red yellow.

Ruby.—This is the rarest and most highly prized of artificial stones. The preparation of topaz furnishes a means of obtaining constantly and at pleasure very fine rubies. The mixture for topaz often gives an opaque mass translucid at the edges, and presenting in its thin plates a color red by transparency. One part of this opaque topaz-matter, and eight parts of strass melted in a Hessian crucible, when left thirty hours in the fire of a potter's furnace, give a fine yellowish crystal similar to strass. Remelted with the blowpipe, this produces rubies of the finest water.

A ruby not so fine, and of a different tint, may be made by employing the following proportions:—

Colorless strass,	1000
Oxide of manganese,	25

Emerald.—The emerald is very easy to imitate. That which succeeds best results from the mixture of the oxide of copper with colorless strass. If oxide of cobalt be added, the green obtained presents blue reflexions. The composition which gives the best imitation of natural emerald is as follows:—

Colorless strass,	1000
Pure oxide of copper,	8
Oxide of chromium,	0·2

By increasing the proportion of chromium or oxide of copper, and adding oxide of iron to the mixture, one may vary the green shade, and imitate peridot or dark emerald.

Sapphire.—To produce a fine oriental blue color, one must employ very white strass, and very pure oxide of cobalt. This composition, put into a luted Hessian crucible, should remain thirty hours in the fire. The proportions are as follow:—

Colorless strass,	1000
Oxide of cobalt,	15

Amethyst.—The color of this stone must be fine and velvety, to be of any value. The formula which succeeds best is the following:—

Colorless strass,	1000
Oxide of manganese,	8
Oxide of cobalt,	5
Purple of cassius,	0·2

Aqua-marina is a gem in little request—even the real stone. As generally met with, it is of a pale emerald tint, but the most valuable kind is colorless like the diamond. It is obtained artificially by mixing—

Colorles strass,	1000
Glass of antimony,	7
Oxide of cobalt,	0·4

Syrian Garnet.—This stone, which was anciently termed *carbuncle*, has a lively color, for which it is much esteemed. It is especially employed for small jewels. The artificial garnet is a kind of dark ruby, and is made after the following formula:—

Colorless strass,	1000
Glass of antimony,	500
Purple of cassius,	4
Oxide of manganese,	4

In the fabrication of artificial stones, there are many precautions to be taken, many points to be observed, which can only be acquired by experience. The materials must be pulverized with great care. The mixtures can only be well made by repeated sifting. The same sieve must not be used for sifting different compositions, whatever care be taken to clean it after each operation. Lastly, to obtain masses well melted, quite homogeneous, without striæ or bubbles, it is necessary to employ substances very pure, and mixed in a state of extreme division; to obtain the best crucibles, to melt with a graduated heat, in a furnace which is quite equal in its maximum temperature; to leave the metal in the furnace during twenty-four to thirty hours, and to cool the crucibles very slowly, that their contents may undergo a kind of annealing.

Colored Flint-Glass.—Assuming as the composition of the glass to be colored the common ingredients and proportions quoted at page 230, and remembering that these materials, when mixed together, are technically termed *batch*, and, when fused with the usual precautions, produce a highly pellucid flint-glass, this may be regarded as the basis of the following colored glasses, given on Mr. Pellatt's authority:—

Soft White Enamel.—To six hundredweight of batch add twenty-four pounds of arsenic, six pounds of antimony.

Hard White Enamel.—To six hundredweight of batch add two hundred pounds of putty prepared from tin and lead.

Blue Transparent Glass.—Six hundredweight of batch colored with two pounds of oxide of cobalt.

Azure Blue.—Six hundredweight of batch with about six pounds of oxide of copper.

Ruby Red.—Six hundredweight of batch with about four ounces of oxide of gold.

Amethyst or Purple.—Six hundredweight of batch with about twenty pounds of oxide of manganese.

Common Orange.—To six hundredweight of batch add twelve pounds of iron ore and four pounds of manganese.

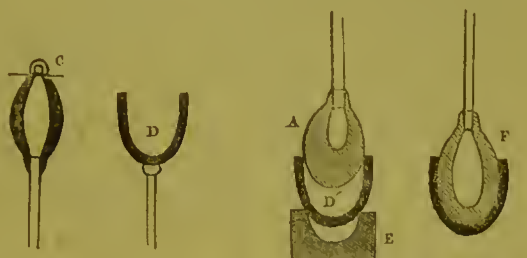
Emerald Green.—To six hundredweight of batch add twelve pounds of copper scales and twelve pounds of iron ore.

Gold Topaz Color.—Six hundredweight of batch with three pounds of oxide of uranium.

Flashing and Casing.—In speaking of the suboxide of copper, it has been stated that the coloring power of this substance is so intense that even a very small quantity of it renders the glass opaque; and allusion was made on that occasion to the process of *flashing*, by which the difficulty is overcome, and which, on account of the facilities it affords for regulating the intensity of the tint, has been extended to the manufacture of articles of every variety of hue. This process consists in coating a layer of colorless, with one of colored glass, which can then be reduced, by grinding, to the proper tint. For this purpose the glass-blower collects the proper quantity of colorless glass on the end of his pipe, rolls it upon the marver, and then dips it for a moment into a pot of melted colored glass, and blows out the two together into a cylinder or globe, which is flatted or *flashed* out in the usual manner. In this manner panes for the glass-painter are formed, which consist of two layers of glass, one colored, the other colorless; and the former can be ground down to any required tint or degree of transparency. An ingenious application of this process is made to vessels of flint-glass, which are colored on the outside in a similar manner, and colorless edges or facets are then produced by cutting through the outer layer of colored glass, into the substratum of colorless glass.

Flint-crystal glass is usually colored by a somewhat similar process termed *casing*, and thus described by Mr. Pellatt. Presuming that any two or more glasses intended for casing have been mixed of the same specific gravity, to give them the capability of harmonizing—that is, of contracting and expanding equally—the blower has to gather a ball of solid glass, intended for the interior layer, in the usual manner, as A, Fig. 194, which, in this instance, may be considered to be of white crystal glass. About the same time his assistant prepares a casing of colored glass, B, knocking off the knob at C, to open and shape it, as D, somewhat like the bowl of a wine-glass, or the broad end of a large egg-shell; this is set into a metal stand, E, on the floor, merely to steady the case or shell, D′; while the blower takes the lump of flint or white glass, A, and gently blows it into the colored case or shell, D′, to which it immediately adheres; and when submitted to the flame of a pot-hole, it is found to weld perfectly, as F. If various coverings are needed, as many colored shells must be prepared as required, and each time melted in by fresh warming, until the entire number are obtained and cased. The whole are afterwards rewarmed, expanded, and shaped into vases, tazzas, or such other articles as the manufacturer requires, by blowing, and the usual appliances of moulds, tools, rotatory motion, &c. When cut through to the crystal in various figures, the edges of the different colors on enamel are seen.

Fig. 194.



In connection with *flashing* and *casing*, may be mentioned a variety of methods of producing colored or variegated or ornamental glass, some of which are very ingenious, and are chiefly derived from the Venetians.

Venetian filigree work is produced in the following manner:—Pieces of *cane*, or solid rods of glass, of different colors, having been drawn out in the same manner as tubes, and whetted off to the required lengths, are arranged in the flutes or internal grooves of a cylindrical mould, A, Fig. 195. The blower then inserts a solid ball of transparent flint-glass, B, Fig. 196, and the whole is exposed to a welding heat, till the canes adhere to the ball. Both are then withdrawn with it from the mould, when the piece presents the appearance represented in Fig. 197. When again heated, drawn, and twisted, the streaks of color produced by the adhering canes become spiral, and ornament the surface. If well softened and marvered before the drawing and twisting, the streaks spread till they meet; or if, before being drawn, the mass be redipped into the pot of crystal glass, and then twisted, the spiral lines of color or enamel become internal. By the repetition of this process, spirals can be formed

Fig. 195.

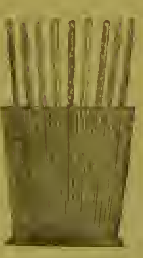


Fig. 196.

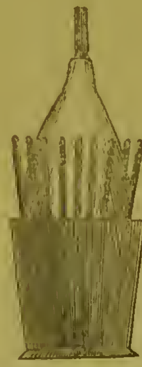
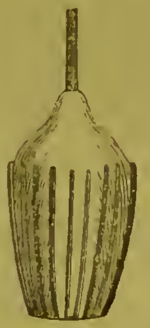


Fig. 197.

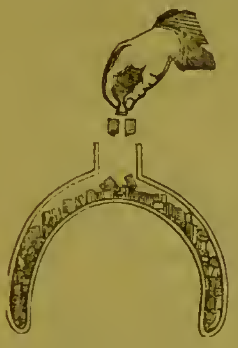


within spirals; and by placing the filigree canes side by side, and welding them together, very curious and intricate patterns are obtained.

The *Venetian ball* is simply a number of pieces of waste filigree glass collected together without regular design; they are then introduced into a globe of transparent glass, which is made to collapse upon the filigree fragments within by suction; that is to say, by the blower drawing in his breath. The round heavy paper-weights, which generally contain regular devices, are formed in the same manner, and the lens-like shape of the crystal enhances the effect by magnifying the incrusted ornament.

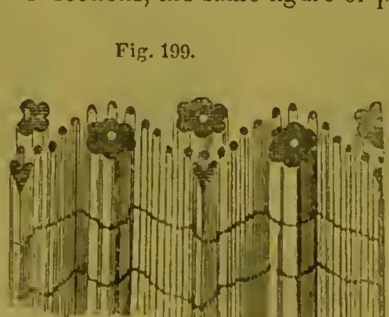
The *mille-fiore* or *star-work* of the Venetians is formed by placing lozenges of glass, cut from the ends of colored filigree canes in the interval between two transparent cones, as shown in Fig. 198, and then, after reheating the whole, exhausting or sucking out the air by means of a blowing-iron attached to the neck, A. The piece being then rewarmed becomes one homogeneous mass, which can be shaped into any required form, for tazzas, paper-weights, *et cetera*. In forming such incrustations, it often happens that, from the unequal contraction between the object and the crystal by which it is surrounded, there is much difficulty in the annealing, and, to avoid the risk of fracture, the contained object must be made of materials expanding and contracting like the glass or crystal itself.

Fig. 198.



Glass-mosaic, which is often confounded with *mille-fiore*, is produced by threads or small canes of variously colored opaque or transparent glass, of uniform lengths, ranged vertically side by side, in single threads or masses, so that the ends shall form grounds agreeably to some prefigured design. When submitted to heat sufficient to fuse the whole, the four sides at the same time being pressed together so as to exclude the air from the intervals between the threads, the result will be a thick slab of variegated glass—Fig. 199—exhibiting, for all parallel sections, the same figure or pattern. Hence, when cut into veneers, either in the direction shown by the dotted lines, or obliquely or longitudinally, it will yield a number of slabs or layers of the same uniform design. The thin rods of glass employed for this purpose are composed of very easily fusible glass of all possible colors and shades, and are prepared in manufactories erected expressly for this purpose.

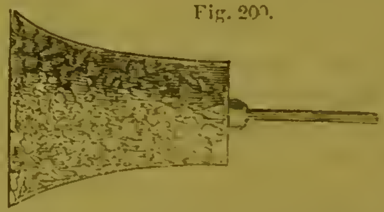
Fig. 199.



In these manufactories, masses of colored glass are prepared, from which a kind of cake is formed, and this is converted, with the aid of a sharp hammer and an anvil, first into slabs, and then into the thin rods above-mentioned. In this form the material is supplied to the artist, who softens it in the flame of a lamp, draws out each rod into a thick thread, and breaks off a piece of the thickness of the intended picture. The pieces are then arranged one after the other, according to the design, on a slab of copper covered with a layer of cement, which serves to fix the picture. When the whole slab is covered, the surface, which is necessarily uneven and irregular on account of the unequal lengths of the rods or threads, is ground and polished. It is unnecessary to observe, that a large mosaic painting formed in this manner is often a work of years.

Venetian frosted glass is obtained by immersing the gathering of hot metal in cold water, quickly withdrawing it, reheating and expanding it by blowing, before it becomes so hot as to melt and weld together the numerous superficial cracks produced by the momentary immersion in cold water. These cracks only penetrate so far as the metal has been cooled by the water, and remain as depressions until the article is finished, when it presents the appearance represented in Fig. 200. The art of making this glass was kept secret by the Venetians, but was rediscovered by Mr. PELLATT a few years ago.

Fig. 200.



Mr. PELLATT has also invented a method of ornamenting glass with delicate white argentine incrustations of dry porcelain clay, cemented into the solid glass. For this purpose the hot prepared cameo, which may be a small bas-relief or cast, is placed upon the red-hot manufactured vessel or other article; a small piece of liquid glass is then dropped on it, and becomes welded; and if rubbed while hot, the upper coat of fused glass will be spread as thinly as possible upon and around the cameo, behind which are driven any air-bubbles that may be entrapped; thus completely isolating the device between the two glasses. The polishing of the exterior layer gives the white figure a silvery appearance; but, of course, the incrustation may be colored before being applied to the glass. These incrustations require very careful annealing.

Venetian vitro-di-trino is a sort of lace-work, formed by intersecting lines of white enamel, or transparent lines of white or colored enamel or transparent glass, the centre of each mesh or diamond inclosing an air-bubble. It is formed by blowing a gathering in the mould with suitable canes arranged in the interior fluting, as shown in Fig. 195, page 241. It is then reheated, further blown and twisted, as for spiral filigree, the canes being left projecting from the outside, like ribs. By the usual manipulation, a cup or conical vessel is formed, marked by oblique lines or spiral projections, as shown in Fig. 201. Another similar piece is then made and turned inside out; the projecting canes on this piece are inside, and the spiral lines reversed. The one piece is then placed under the other, as shown in Fig. 202, and the two are welded together. The ribs or flutes projecting from the two surfaces in contact inclose, during the welding, a portion of air in each diamond, which air gradually assumes the bubble-shape. The vessel is then finished in the ordinary manner, and the lines exhibit the most beautiful regularity, as shown in Fig. 203.

Fig. 201.

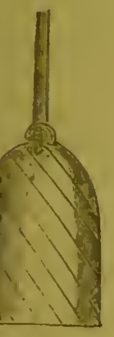


Fig. 203.

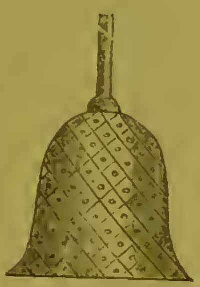
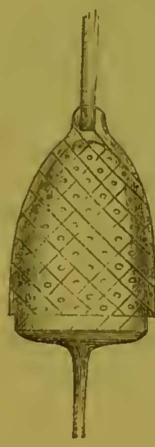


Fig. 202.



Aventurine Glass is an easily fusible brown, or, in thin layers, yellow glass, interspersed with numerous fine yellow laminæ or spangles with a metallic lustre, which give it a peculiar shining appearance. The method of manufacture was long kept secret by the Venetians. It was commonly supposed that aventurine glass was produced by melting scales of metal or mica with the glass; but this opinion was thought to be overthrown when GAHN observed that, under the microscope, these scales appeared as regular three or six-sided tables, perfectly crystalline in structure. He discovered, in fact, that the spangles consisted of metallic copper, crystallized in the form of flat segments of a regular octahedron. FREMY and CLEMANDOT succeeded, however, in preparing this glass by fusing together, for twelve hours, the following mixture:—

Pounded glass,	300	parts,
Copper scales,	40	,,
Iron scales,	80	,,

and afterwards cooling slowly. The glass obtained was somewhat deficient in lustre, but, like the true aventurine, it contained copper diffused through it in octahedral crystals.

GLASS-PAINTING.—Painting on glass is performed by means of a vitreous mixture termed the flux, combined with a pigment prepared from some metallic oxide. The flux and oxide are simply that combination of ingredients which is necessary to produce a highly fusible colored glass of the required hue; this mixture is reduced to a state of fine powder, rubbed up in oil of turpentine, boiled oil, or sometimes simply with water, and laid upon the glass to be painted, by means of a brush. The glass thus painted or stained with the intended design is then exposed to a heat sufficient to vitrify the mixture of color and flux, without melting the glass; in other words, the painting is said to be burnt in; the ingredients of which it is composed are converted into a colored glass or transparent picture, while the pane or other article on which it is laid, is only sufficiently softened to cause the complete adherence of the colored glass to its surface.

It is evident, therefore, that the fusing-point of the pigment must be much lower than that of the glass to be painted. Indeed, it is necessary that the former should vitrify at a temperature at which the latter does not sensibly soften; for any considerable softening or yielding of the glass would distort the design. Hence the manifest inapplicability of crystal or lead-glass for painted articles, on account of its great fusibility. On the other hand, common window-glass, or even plate-glass, may be successfully used, and, best of all, the hard Bohemian glass, which contains potassa for a base.

When the coloring oxides employed are such that they are not injuriously affected by the oxides of lead and of bismuth, the flux is usually composed of the following ingredients:—

	Parts.
Quartz in powder,	100
Oxide of lead,	125
Oxide of bismuth,	50

But if these oxides exert an injurious action on the coloring matter, and tend to change its shade, the subjoined composition is used:—

	Parts.
Quartz in powder,	100
Fused borax,	75
Nitrate of potassa,	12·5
Carbonate of lime, free from iron,	12·5

To either of these mixtures or fluxes the proper coloring matter is added, and the composition so formed is introduced into a crucible, and melted into a colored glass. The latter is then reduced to a fine powder, mixed, as has been stated, with oil of turpentine, and used as a common pigment for painting on the less fusible glass. In this operation, a cartoon, or drawing upon paper, is placed below the glass, and the colors are applied on the corresponding lines. In preparing painted sheets or panes of glass, brown or black outlines are generally traced on the one side of the sheet, whilst the colors are laid on the other side; but in painting vessels or other articles, this is not the practice.

One great difficulty of the glass-painter consists in this, that the colors which he lays on have not the same appearance as they are intended to assume in the finished work. The difficulties of the artist on glass, says Mr. TOMLINSON, are of a much more formidable character than those of the artist on canvas; he must be as good an artist as the latter, but he must also have the faculty of seeing his effects as they will appear after the firing, and not as he lays them on; for the coloring oxides which he employs, especially when mixed up in their fluid vehicles, are dark, dusty, and disagreeable in color, and have nothing in common with the bright and beautiful effects we admire in a stained-glass window. When the same figure or pattern is to be repeated many times, it is, in some cases, printed on the glass with a gentle pressure from an engraved metallic plate, or wooden block, boiled oil being used as the vehicle for the coloring oxide. The pane, having been prepared either by painting or printing, is exposed in an oven or muffle to a temperature sufficient to fuse the vitreous flux and dissolve the coloring material. The glass selected for the purpose of the stainer should be clear and colorless, in order to bring out the colors well; and difficult of fusion, so that the flux and metallic oxide may form a colored glass upon its surface before it shows any tendency itself to fuse. A glass containing a small proportion of alkali, such as crown-glass, is fit for the purpose.

SPUN GLASS.—There is no one who has not heard statements relative to the discovery of a malleable glass, one memorable instance of which is mentioned in the Historical Notice, page 186. If, by malleable glass, be understood a glass capable of being spread out into thin plates under the action of the hammer at the ordinary temperature, everything leads to the belief that this marvel never was, and will not for a long time be realised. If, on the contrary, it means only the ductility of incandescent glass, there remains in this respect little to be accomplished. It is, in fact, on this property that the whole art of the glass-maker depends. But whilst, in the ordinary operations of glass-making, the ductility of the glass is never pushed to its utmost limits, these limits are almost reached in the curious art of spinning glass into thread.

The art of spinning glass consists in drawing it out into threads when softened, by means of a wheel on which the thread is wound. By this means the art has been attained of spinning glass with astonishing rapidity. The drawn-out end of a glass rod has only to be attached to a revolving drum, whilst the rod whence the thread proceeds is held in the glass-blower's lamp, in order to obtain in a few minutes several ells of spun glass. The thread possesses, of course, the color of the glass; but its tenuity is so great that the color is scarcely perceptible, unless very deep shades have been employed.

It has already been stated that when a piece of hollow glass is drawn out, the hole is always preserved, however fine be the thread. M. DEUCHAR took a piece of thermometer tube, the interior diameter of which was very small, and drew it out into threads. The drum which he used was three feet in circumference, and as it made five hundred turns per minute, he obtained thirty-two thousand ells of thread per hour; so that the thread was of extreme fineness, and its interior diameter was scarcely calculable. This thread was, however, hollow; for being cut into pieces of an inch and a half in length, and placed on the receiver of an air-pump, one end inside and the other out, it allowed the mercury to pass through in small shining filaments when a vacuum was made in the receiver.

The thread obtained from a small piece of window-glass, cut with a diamond, presents a very brilliant lustre; seen with the microscope, it exhibits a flattened form, with four very distinct right angles. It is very probable that it owes to this particular form the superiority of its lustre, for the threads obtained from round pieces of glass had always a dull appearance.

When glass of different colors is fused or welded together in one tube, the thread obtained from it preserves all the original colors without any mixture taking place, or any interruption being observed; but most of the colors become tarnished by the operation, particularly the yellow, which disappears: the black even sometimes passes to brown: the purple and green are a little altered, but the blue stands well.

The samples of spun glass are as pliable as silk, and may easily be wound in the manner of common thread, and employed as ornaments. To the touch they feel like hair, and like it may be curled in a permanent manner by rolling them on a hot iron. Threads from black glass have so much resemblance to black hair, that they are often confounded. It is well known that in the last century perukes were manufactured of glass thread, which is sometimes still used to make very brilliant head-dresses. Its glossy appearance, its great durability when not exposed to rough usage, as well as the low price of glass, naturally suggested to manufacturers the advantage of making it a material for spun fabrics. It has even been woven into stuffs, but hitherto this curious manufacture does not appear to have been attended with much success. It has been alleged, indeed, not without reason, that articles of clothing made of glass might be attended with some danger from the filaments becoming detached, and being drawn into the lungs by respiration. KNAPP states, however, that this branch of manufacture has lately been revived with success by OLIVI, DUBUS-BONNEL, and BOUILLON; and that DUBUS, in particular, is said to have succeeded in producing glass thread that can be knotted, and woven on JACQUARD'S loom into fabrics which are equal in every respect to the most beautiful gold and silver brocade. He adds that the particulars of this manufacture have not yet been made public, and the Editor cannot help thinking that its success has been greatly exaggerated.

VII. SOLUBLE GLASS.—Soluble glass is a compound the knowledge of which would have spared the glass-makers many faults. It is, as has been stated, a simple silicate of potassa or soda, or a double silicate of these two bases. What is remarkable, this body is soluble in boiling water without a residue, though scarcely affected by contact with cold water. Nevertheless, it is very evident that such a glass must be strongly hygrometrical, and, among the numerous examples which might be cited, the Editor limits himself to the following, to show the inconveniences which arise from this. In 1780, Bohemian glasses, the process for which was then a recent importation, were made simultaneously in France by the two following receipts:—

	At Bayel in Champagne.	At Elmbac in les Vosges.
Silica	100	100
Potassa,	100	100
Lime,	none	100

Now, while the Vosges glass was unalterable by the air, that of Champagne was wanting in clearness, brilliancy, and solidity, and attracted the moisture of the atmosphere to such an extent, that the hollow feet of drinking-glasses became filled in the warehouses with a saturated solution of carbonate of potassa. To this fact, one might add many others which would prove the indispensable necessity of lime or of oxide of lead, for the making of glasses to be capable of resisting the action of water or of moist air.

Soluble silicated alkali or water-glass may be prepared by various processes. If sand be used, fifteen parts of fine sand, thoroughly incorporated with eight parts of carbonate of soda, or with ten of carbonate of potassa, and one of charcoal, fused in a furnace, will produce a silicated alkali which is soluble in boiling water. Messrs. Ransome obtained this silicated alkali by dissolving broken flints in a solution of caustic alkali at a temperature of 300°.

This water-glass has been applied to several important purposes, three of which are epecially noticed.

To protect Building-stones from decay.—The stone surfaces of buildings, by being exposed to the action of the atmosphere, become liable to disintegration from various causes. Moisture is absorbed into their pores. The tendency of their particles to separate in consequence of expansion and contraction, produced by alternation of temperature, is thus increased. Sulphurous acid is always present in the atmosphere of coal-burning cities, and cannot but corrode the calcareous and magnesian ingredients of oolites and dolomites. It is true that good stone resists these sources of injury for an indefinite time, but such a material is rarely obtained. As a preventive of destruction, whether arising from physical or chemical causes, it has been proposed to saturate the surface of the stones with a solution of water-glass.

It is well known that the affinity of silica for alkali is so feeble, that it may be separated from this base by the weakest acids, even by carbonic acid. According to the expectation of those who recommend the silification of stone, the carbonic acid of the atmosphere will set the silica free from the water-glass, and the silica thus separated will be deposited within the pores and around the particles of the stone. The points of contact of these particles will thus be enlarged, and a sort of glazing of insoluble silica will be formed, sufficient to protect the stone from the effects of moisture, *et cetera.* This cause of protection applies chiefly to sandstones. But wherever carbonate of lime or carbonate of magnesia enters notably into the composition of the building stone, then an additional chemical action, also sheltering the stone, is expected to take place between these carbonates and the water-glass. An insoluble salt of lime may be looked for, whenever a solution of water-glass is made to act on the carbonates of lime or magnesia existing in oolitic or dolomitic building stones.

This expectation, however, has not been altogether realized by experiment. Mr. Charles A. Smith, a gentleman eminently conversant with building materials, immersed a piece of Caen-stone in a solution of silicate of potassa in the month of January, 1849. This fragment, together with a portion of the block from which it had been detached, was placed on the roof of a building in order that it might be fully exposed to the action of atmosphere and climate. After five years the silicated and the unsilicated specimens were found to be both in the same condition, the two being equally corroded. But whatever ultimate results may ensue from this process, the immediate effects on the stone are remarkable. Two portions of Caen-stone were exhibited, one of which had been soaked in a solution of water-glass two months before. The surface of the unsilicated specimen was soft, readily abraded when brushed with water, and its calcareous ingredients dissolved in a weak solution of sulphurous acid. The silicated surface, on the other hand, was perceptibly hard, and resisted the action of water and of dilute acid when similarly applied.

Another proposed use of the water-glass is that of *hardening cements, mortar, et cetera,* so as to render them impermeable by water.

Fourteen years since, Anthon of Prague proposed several applications of the water-glass. Amongst others he suggested the rendering mortars waterproof. He also suggests that this substance might be beneficially employed as a substitute for size in whitewashing and staining walls. It was demonstrated by several experiments that carbonate of lime, mixed up with a weak solution of water-glass, and applied as a whitewash to surfaces, was not washed off by sponging with water, and that common whitewash, laid on in the usual manner with size, was rendered equally adhesive when washed over with water-glass.

The Stereochrome of Fuchs.—The formation of an insoluble cement by means of the water-glass, whenever the carbonic acid of the atmosphere acts on this substance, or whenever it is brought in contact with a lime-salt, has been applied by Fuchs to a most important purpose. The stereochrome is essentially the process of fresco-sicco invested with the capability of receiving and perpetuating works of the highest artistic character, and which may be executed on a vast scale. This chemist's method is as follows:—

Clean and washed quartz-sand is mixed with the smallest quantity of lime, which will enable the plasterer to place it on the wall. The surface is then taken off with an iron scraper, in order to remove the layer formed in contact with the atmosphere; the wall being still moist during this operation. The wall is then allowed to dry; after drying it is just in the state in which it could be rubbed off by the finger. The wall has now to be fixed, *i. e.* moistened with water-glass composed as follows:—

	Centesimally.
Silicic acid,	23·21
Soda,	8·90
Potassa,	2·52
Water,	65·37
	100·00

The specific gravity of the solution is to be 3·81. This operation is usually performed with a brush. The wall must be left in such a condition as to be capable of receiving colors when afterwards painted on. If, as frequently happens, the wall has been too strongly fixed, the surface has to be removed with pumice, and to be fixed again. Repaired in this manner, the wall is suffered to dry. Before the painter begins, he moistens the part on which he purposes to work with distilled water, squirted on by a syringe. He then limns: if he wishes to repaint any part, he moistens again.

As soon as the picture is finished, it is aspersed over with water-glass. After the wall is dry, the syringing is continued as long as a wet sponge can remove any of the tint. An efflorescence of soda sometimes appears on the picture soon after its completion. This may either be removed by syringing with water, or may be left to the action of the atmosphere. Not to dwell on the obvious advantages possessed by the stereochrome over the real fresco—such as its admitting of being retouched and its dispensing with joinings—it appears that damp and atmospheric influences, notoriously destructive of real fresco, do not injure pictures executed by this process.

The following crucial experiment was made on one of the pictures. It was suspended for twelve months in the open air, under the principal chimney of the New Museum at Berlin; during that time it was exposed to sunshine, mist, snow, and rain, and nevertheless retained its full brilliancy of color.

The stereochrome has been adopted on a grand scale by **Kaulbach**, in adorning the interior of the great national edifice at Berlin, already alluded to. These decorations consist of historical pictures—the dimensions of which are twenty-one feet in height, and twenty-four and three-quarters in width—single colossal figures, friezes, arabesques, *et cetera*. On the effect of the three finished pictures, it has been remarked by one whose opinion is entitled to respect, that they have all the brilliancy and vigor of oil paintings, while there is the absence of that dazzling confusion which new oil paintings are apt to present, unless they are viewed in one direction, which the spectator has to seek for.

Mr. A. **Church** has suggested that, if the surface of oolitic stones—such as Caen-stone—is found to be protected by the process already described, it might be used, as a natural *intonaco*, to receive colored designs, *et cetera*, for exterior embellishings; the painting would then be cemented to the stone by the action of the water-glass.

Mr. **Church** has also executed designs of leaves on a sort of terra-cotta, prepared from a variety of **Way**'s silica rock, consisting of seventy-five parts clay, and twenty-five of soluble silica. This surface, after being hardened by heat, is very well adapted for receiving colors in the first instance, and retaining them after silication.—*Timbs.*

Kuhlmann remarks that the contact of lime with silicate of potassa, always determines the decomposition of this salt and its transformation into silicate of lime, which retains the coloring matter, and even carbonic acid, as lately supposed by M. **Fuchs**; but when the colors are applied on bodies which do not react on the soluble silicate—such as wood, iron, glass, *et cetera*—it becomes necessary to seek for conditions of insolubility in the reaction of the coloring matter on this silicate. On wood the difficulty may be removed by the application, before the silicious painting, of a sufficiently thick covering of chalk, which may be applied with zinc, or fixed with a very little silicate.

Even when the decompositions of the alkaline salt are determined by the coloring matter itself, there still remains one serious inconvenience: this is the exudation, during damp weather, of carbonate of potassa to the complete expulsion of the salt. This chemist has a long time sought for a remedy for this serious injury to silicious paintings; he often conferred on this subject with those members of the Academy best acquainted with vitrification, and having been aided by their advice, **Kuhlmann** sought in various chemical changes for a remedy, and ascertained that washing the painting with a weak solution of chloride of ammonium, enables one to attain absolute insolubility of the color, but chloride of potassium remains, which spoils its brilliancy until its complete expulsion by repeated affusion with water. As the number is but small of chemical reagents, which have the property of consolidating potassa by forming with it insoluble compounds in the color itself, but without eliminating it, perchloric acid and hydrofluosilic acid are the chemical agents which first offer themselves to the mind.

In a theoretic point of view, there only remained to choose between them; but, in an industrial sense, hydrofluosilic acid was the only one on which his mind fixed itself. He ascertained so frequently that careful washing with hydrofluosilic acid much augmented the stability of these colors, and determined their complete insolubility, that he did not hesitate to point out the utility of this agent in every kind of silicious limning, but especially in painting on glass, provided that it is used in very weak solution; for in the concentrated state it has the remarkable property of dissolving most of the oxides, which property will be very valuable for industrial purposes, when this acid can be sold at a moderate price.

The silicious colors on glass have a certain semi-transparency which it is important to preserve, but which gradually diminishes by the action of water. Glass painted with silicates has been subjected to boiling in water without the colors being detached; these tints have even appeared brighter when seen by reflected light; but if, after this apparent improvement, the effect is examined by transparency, the hues are found to have become duller, which is to be attributed to the opacity which they had acquired, resulting from the solution of a portion of silicious cement, which acts on these colors as oil does on paper. The careful employment of hydrofluosilic acid gives a complete insolubility to paintings on glass; but, like chloride of ammonium, it slightly diminishes the transparency. One might perhaps apply, at long intervals, a slight varnish of pure silicate of potassa to paintings on glass which are exposed to rain. Long experience can alone determine this point. This varnish would advantageously replace the essences now used in the application of certain colors on glass and porcelain; it would not, like the essences, be subject to the drawback of spoiling certain colors by the reduction of the oxides or of the coloring salts.

Statistics.—Considering the vast importance of glass, and the peculiar facilities possessed by Great Britain in her ample stores of coal, and the possession of nearly all the materials for the manufacture, it might have been imagined that this country would not only have fully supplied her own wants, but would long ago have furnished a large portion of the world with glass, as with many other exports. It might be supposed, also, that the various necessary, convenient, and ornamental purposes to which glass is applied, would have been held as a sufficient reason for exempting it from taxation, or at least for reducing the duties to the lowest possible limit. But so far was this from being the case, that the most exorbitant duties were imposed, and were exacted in the most oppressive manner; which not only limited the demand for glass, by directly increasing the price, but operated indirectly with most injurious effect, by fettering the operations of the manufacturers, and preventing them from making experiments, and introducing new processes and improvements.

As illustrative of the amount of the duties, which are exhibited more at large in the appended tables, it will be seen that in 1813 they were raised to not less than four pounds eighteen shillings a hundredweight on plate and flint glass, and three pounds thirteen shillings and sixpence on crown. With such enormous duties on one of the modern necessaries of life, the result of ignorant legislation, it was impossible for this country to enter into fair competition with other nations, or even to keep pace with a rapidly increasing population. On the contrary, despite the increase in population, and the still greater increase in wealth in the interim, the consumption of flint and plate glass in 1813, and many subsequent years, was less than it had been in 1794, when the duty on these glasses was only one pound two shillings and twopence farthing a hundredweight. Again, it is stated by the late Mr. PORTER, that in 1801, with a population of only sixteen millions, the quantity of glass used was three hundred and twenty-five thousand five hundred and twenty-nine hundredweight; and in 1833, with a population of twenty-five millions, the quantity was no more than three hundred and sixty-three thousand four hundred and sixty-eight hundredweight—an increase of one-eighth, while the population had increased in the proportion of one-half.

By the imposition of the income-tax, the late Sir ROBERT PEEL was enabled to abolish, along with many other injurious indirect taxes, the excise duties on glass, which were repealed from the 5th April, 1845; and MACCULLOCH justly remarks, that the beneficial influence of this liberal and most judicious measure is obvious in the improved quality, the increased cheapness, and greater variety of descriptions of glass in the market. At the meeting of the Society of Arts, in 1856, to which reference has already been made in the course of this article, Mr. W. A. SWINBURNE, of the celebrated glass-making house of that name, alluded to the different price of glass in former times, as compared with the present; speaking of three shillings and sixpence or four shillings a foot as having been paid to glaziers now living for glazing ordinary-sized crown glass in sashes, for which now, perhaps, only as many pence could be obtained. In the case of plate-glass, he held in his hand a tariff used by their house, dated 1771, two years before the establishment of the British Plate-Glass Company, wherein the price of a chimney mirror fifty inches long by forty inches wide, a very usual size, and now in common demand, was quoted at sixty-one pounds three shillings! The price of this plate before the repeal of the duty in 1845, was nine pounds nine shillings to ten pounds; after the repeal of the duty, about eight pounds; in 1854, four pounds ten shillings; and in 1855-6, about four pounds four shillings. So much had the public benefited by the reduction of the price of glass.

But, as may be supposed, this reduction in price, as well as the great improvement in quality, did not solely arise from the mere repeal of the duties. It arose also, in great measure, from the removal of those intolerable fetters which were previously imposed on the manufacturer by the excise regulations. During the excise reign, says Mr. PELLATT, in his *Curiosities of Glass-making*, no pot could be moved from the spot where it was dried, to be placed in the annealing arch, without a notice in writing to the supervisor; a second notice was required for gauging; a third for setting it in the furnace; again, for filling the pot; and another for lading it out; whilst the maker was forced to comply strictly with the act of parliament, by giving the officer six hours' notice for each of these intricate and vexatious requirements.

Again, with reference to the subject of annealing, the same able writer remarks:—When the excise upon glass existed, the lear was secured by fastenings and locks—supplied by the Government officer at the expense of the trader, and safely secured every Friday or Saturday, and not re-opened till the Monday following. During the whole of the week, the officer had the surveillance of the lear, but especially of the sorting-room, at the delivery end of the lear, which was only entered at the stipulated act of parliament periods. If a link forming part of the endless chain running under the lear, connected with the machinery drawing down the pans, accidentally broke in the night, and the officer should happen to be absent—which was rather the rule than the exception—either the whole works must be stopped, or some mode adopted for the learman to repair the mischief not strictly in keeping with the act; so that while the principal was quietly reposing in his bed in imaginary security, his servant, unknown to him, had almost necessarily incurred ruinous excise penalties. The excise officer gauged the liquid glass in the pots, which he had the option of charging by weight, at a specific gravity of 32·00; and should the manufactured annealed goods ultimately not amount to two-fifths of that estimate, he had to pay the difference. The lear charge was always considered to be the chief security, as indeed it really was; still, with the utmost excise vigilance, the trader occasionally defrauded; but owing to the great heat of the arch, and the usual excise securities, the revenue was, on the whole, well secured at the lears. Had the lears or kiln been the only departments of the works under excise survey, the manufacturer would not have been so much inconvenienced. The surveillance of the pots was his chief annoyance, since it required endless trouble, and subjected the manufacturer to danger of exchequer prosecutions. To throw into the pots ever so small a piece of metal, during the working, incurred a penalty of fifty pounds for every offence. Neither plate-glass nor bottle-glass manufacturers were subject to the surveillance of the pots: this made it exclusively injurious to the flint-glass maker, and was almost a prohibition of alteration of tint, or experiments, and consequent improvements. It is matter of astonishment how flint-glass works existed at all, under such a concentration of commercial and manufacturing hinderances as were imposed by the excise regulations; happily, the incubus exists only in reminiscence.

While the greatest stimulus was given to the crown and sheet glass manufacture by the abolition of the duty in 1845, that abolition has produced a somewhat paradoxical result, which is thus stated by Mr. HENRY CHANCE:—While the quantity of glass made has increased in the proportion of three to one, the number of manufacturing firms has diminished in the proportion of one to two. In 1844 there were fourteen companies engaged in the manufacture. In 1846 and 1847, following the repeal of the duty, the number had increased to twenty-four. The glass trade, after the removal of the heavy burden imposed upon it, seemed to offer a fair opening for money seeking investment. The demand for glass was so great that the manufacturers were in despair. Glass-houses sprung up like mushrooms. Joint-stock companies were established to satisfy the universal craving for window panes. And what was the result? Of the four-and-twenty companies existing in the year 1847, there were left, in 1854, but ten. At this time there are but seven in the whole United Kingdom. Two, established in Ireland, have ceased to exist. In Scotland, the Dumbarton works, once famous, were closed in 1831, by the death of the partners, afterwards re-opened, and again closed. The seven now existing are all English.

While thus diminished in number, the immense extent and resources of the principal great glass-houses now existing may be inferred from the fact already alluded to, namely, that the firm of CHANCE and Company executed the large order in sheet-glass for the Great Exhibition structure of 1851 without materially affecting their power of executing their general orders. In such immense establishments, experiments, now untramelled by the meddling officiousness of an absurd legislation, can be executed on a large scale, and vast improvements have been effected. Minor and apparently unimportant changes, perceptible only to those near at hand, have in silence done their work.

Still, as one of the eminent members of the firm above referred to remarks, the development both of the processes and applications of the glass manufacture is incomplete. Sir JOSEPH PAXTON's glass arcades, stretching over the streets of London, and Dr. SLEIGH's city of glass, in which invalids will inhale the gentle air of Madeira,—these are faint foreshadowings of the destiny of this wonderful substance. And, perhaps, the day may come when some future chronicler of glass shall smile at the barbarians of the nineteenth century, who could not make window-glass without defects, and shall exhibit those defects as the curiosities of a by-gone age.

The annexed table, from MACCULLOCH, shows the state of the manufacture, quantity exported, and amount of duties, a few years previous to their repeal :—

I. Account exhibiting the Quantities of the different descriptions of Glass manufactured during each of the Three Years ending with 1842, with the Quantities exported, the Rates and Produce of the Duties, *et cetera.*

Description of Glass.	Quantity manufactured.	Quantity exported.	Rate of Duty.	Gross Amount of Duty.	Drawback on Glass exported.	Nett Amount of Duty Excise, after deducting drawback and other legal allowances.
	Cwts.	Cwts.		£	£	£
Flint-Glass. 1840	101,889	19,913	To 15th May, 1840, 18s. 8d. per cwt.; since, 18s. 8d. per cwt. and 5 per cent.	101,029	21,199	79,830
Ditto, ... 1841	97.524	20.516		95,565	22,605	72,9[illegible]
Ditto, ... 1842	83,653	13,696		81,973	15,098	66,875
		Sq. feet.				
Plate-glass,........ 1840	33,623	52,879	To 15th May, 1840, £3 per cwt.; since, £3 per cwt. and 5 per cent.	104,117	7.412	96.705
Ditto, ... 1841	27,639	121,113		87,061	17.483	69,578
Ditto, ... 1842	21,528	68,318		67,812	9.866	57,946
		Cwts.				
Crown-glass, ... 1840	129,978	15,318	To 15th May, 1840, £3 13s.6d. per cwt,; since, £3 13s. 6d. per cwt. and 5 per cent.	492.962	73,530	417,497
Ditto, ... 1841	116,895	19,118		451,064	92,070	357.337
Ditto, ... 1842	97,495	12·369		376.205	60.891	313,323
German sheet-glass, 1840	16,859	8,219	To 15th May, 1840, £3 13s.6d. per cwt.; since, £3 13s. 6d. per cwt. and 5 per cent.	63,986	33.604	30.382
Ditto, ... 1841	20,855	8,781		80.473	36.876	43.597
Ditto, ... 1842	25,500	7,701		98,397	32,348	66,049
Broad sheet-glass, .. 1840	9,051	1½	To 15th May, 1840, £1 10s. per cwt.	13.915	2	13,913
Ditto,.. 1841	....	....	To 15th Aug. 1840, £1 10s. per cwt. and 5 per cent.; since, £3 13s. 6d. per cwt. and 5 per cent.			
Ditto, ... 1842	....	....				
Common bottle-glass,1840	525,574	292,887	To 15th May, 1840, 7s. per cwt.; since, 7s. per cwt. and 5 per cent.	189,883	103.926	85,957
Ditto, ... 1841	501,177	310,937		184,174	114,109	70,065
Ditto, ... 1842	390,482	225,633		143,496	82,915	60,581
Total nett revenue collected during the three years ending with 1842,...............						£1,902,595
Annual average nett revenue of the three years ending with 1842,......................						£ 634,198

All kinds of glass may now be imported free of duty, except flint cut glass, flint colored glass, and fancy ornamental glass of every description, on which there remains a customs' duty of ten shillings the hundredweight. The residuary customs' duty of one shilling and sixpence a hundredweight on shades and cylinders, and any kind of window-glass, white, or stained of one color only, expired on the 5th April, 1857.

II. A return of the Rates of Duty on Glass in 1813, with the Quantities of each Kind of Glass retained for Home Use, and the aggregate Nett Revenue in each Year, from 1813 to 1842, both included, noting the Periods when any Alteration of the Duty took place, and the Amount of such Alterations.

	Flint.	Plate.	Crown.	German sheet.	Broad.	Common bottle.	Total.	Period and amount of alteration of duty.	Aggregate nett revenue.
Rate of duty in 1813, Per cwt.	98s.	98s.	73s. 6d.	73s. 6d.	30s.	8s. 2d.			
Years.	Quantities of glass retained for home use.								
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.		£
1813	23,370	9,398	84,441	..	6,994	47,350	171,553		500,850
1814	24,227	6,778	84,251	..	8,628	140,252	261,136		530,791
1815	24,911	419	77,485	..	8,452	129,461	240,728		473,780
1816	20,011	..	56,151	..	6,140	160,221	242,523		353,188
1817	22,117	1,739	76,561	..	8,374	123,881	232,692		461,849
1818	26,978	6,391	88,893	..	8,319	201,795	332,376		584,399
1819	28,809	6,473	90,726	..	8,267	238,463	372,738	From 5th July, 1819, the duty on plate-glass reduced from £4 18s. to £3 per cwt.	606,176
1820	24,745	8,735	74,183	..	7,782	171,495	286,940		500,595
1821	21,927	9,718	86,384	..	8,085	137,117	263,181		521,075
1822	21,400	9,562	95,510	..	8,353	154,492	289,317		559,029
1823	21.829	11,607	101,392	..	9,172	198,456	312,456		607,378
1824	24,954	13,543	123,845	..	9,295	238,725	410,362		728,342
1825	34,184	15,082	140,298	..	8,347	251,932	449,843	From 5th July, 1825, the duty of £4 18s. on flint-glass repealed, and a new duty of £12 10s. for every one thousand pounds of fluxed materials for flint-glass imposed.	772,303
1826	47,090	12,527	115.731	..	8,113	282,512	465,973		720,920
1827	46,688	14,209	114,381	..	7,611	239,794	422,683		699,726
1828	54,255	17,096	121,158	..	6,970	254,787	454,266	From 5th July, 1828, the duty on common bottle-glass reduced in Great Britain from 8s. 2d. to 7s. per cwt., and the duty on every description of glass assimilated throughout the United Kingdom.	752,097
1829	50,869	13,925	92,252	..	6,864	218,901	382,811		609,406
1830	49,353	12,677	80,926	..	4,845	180,945	328,746		542,261
1831	49,608	14,373	88,688	..	5,915	150,520	299,104		531,718
1832	51,586	11,554	86,007	179	5,304	158,719	313,349	From 10th October, 1832, the duty on fluxed materials for flint-glass reduced from £12 10s. per one thousand pounds to 20s. for every one hundred pounds.	558,423
1833	54,818	13,893	105,134	..	6,306	164,000	344,151		645,781
1834	52,890	16,306	106,389	..	6,766	194,143	376,494		664,391
1835	43,936	16,941	111,651	4,248	5,847	201,613	384,236	From 10th October, 1835, the duty on fluxed materials for flint-glass reduced from 20s. to 6s. 8d. per one hundred pounds.	640,149
1836	86,866	19,993	117.041	..	7,629	249,145	480,674		663,162
1837	78,121	21,640	101,309	707	7,190	247,446	456,413		608,993
1838	81,594	23,992	113,756	2,262	6,575	243,046	471,225		667,998
1839	82,309	26,465	113,340	5,170	8,514	252,808	488,606		691,467
1840	82,486	31,200	111,316	7,914	9,049	232,834	473,799	From 15th May, 1840, the duty on every description of glass increased 5 per cent.; and from 15th August, 1840, the duty on broad glass increased from £1 10s. to £3 13s. 6d. per cwt.	724,343
1841	71,444	22,088	93,033	11,298	..	190,257	391,120		613,588
1842	68,098	18,396	81,715	17,117	..	161,537	346,863		563,437

The following tabular statement, exhibiting the amount of the imports of the different kinds of glass enumerated, for the three years ending 31st December, 1855, and the exports of glass, of *foreign and colonial manufacture*, during the same period, is extracted from the Trade and Navigation Returns :—

		IMPORTS.				EXPORTS.		
		1853.	1854.	1855.		1853.	1854.	1855.
Window-Glass, and Shades and Cylinders,....	Cwts.	27,577	31,639	25,420	......	5,485	3,012	1,126
Plate-Glass, ...	Lbs.	221,304	794,194	749,151	......	16,415	14,175	21,747
White Flint-glass Goods—except bottles—not cut, engraved, or otherwise ornamented,....	Lbs.	106,621	358,472	378,065	......	15,980	4,584	3,039
All Flint Cut Glass, Flint Colored Glass, and Fancy Ornamented Glass, ...	Cwts.	6,893	10,692	9,402	......	1,143	846	585

The above exports refer to glass of foreign and colonial manufacture. The great falling of in these exports during the years 1854 and 1855, is obviously attributable to the war with Russia; but this effect scarcely appears in the following statement of the exports and declared value of glass *of British manufacture:—*

	Hundredweights exported.				Declared value.		
	1853.	1854.	1855.		1853.	1854.	1855.
Flint-Glass,	47,548	53,072	39,283	......	£162,849	180,896	141,[illegible]
Window-Glass,	39,158	34,522	21,473	......	58,503	57,761	[illegible]
Bottles,	457,787	481,262	513,128	......	248,458	274,832	[illegible]
Plate-Glass—value only,					48,730	35,755	[illegible]
					£518,540	£549,244	£5[illegible]

It is worthy of remark, that in the year 1844, the year before the excise duties were repealed, and with all the advantage of a drawback, the total exports of glass, of British manufacture, were only of the declared value of twenty-six thousand six hundred and ninety-four pounds; whereas, it will be seen from the preceding table, that in 1855, or ten years after the repeal of the duties, they amounted in value to upwards of half a million sterling.

GLYCERIN.—The basic principle of the several substances contained in the fats of animals, as also of several compounds of vegetal origin, has been called *glycerin*. Scheele, its first discoverer, named it *the sweet principle of fat;* but since then, the several investigators who have worked upon the subject have modified this title to that above given, from the Greek word, signifying *sweet*. As already noticed—see vol. i., page 406—this body has not as yet been fully investigated, and considerable diversity of opinion exists regarding its origin and nature. It is generally acknowledged to be an oxide of a compound radical, which, upon the decomposition of the stearin, margarin, or olein of the fats, assimilates water, and acquires the composition which analysis has assigned to glycerin. Respecting the nature of this radical, much speculative reasoning has been indulged in. Berzelius designated it *lypyl*, and contended that the definite bodies in the natural fats were salts of the fatty acids, with the oxide of this radical. Löwig, on the contrary, with whom many concur, terms it *glycil;* all, however, seem to have attributed to it the composition $C_3\ H_2$, and agree that, by the assimilation of oxygen and the elements of water, it becomes $C_6\ H_8\ O_6 = 2\ (C_3\ H_2) + O_2 + 4\ HO$.

Preparation and Properties.—Originally, glycerin was prepared by a rather troublesome process, and necessarily in small quantity. Olive oil, or any of the natural fats, was boiled with litharge—oxide of lead—and water, till saponification was effected; the fluid matter remaining was decanted, and submitted to the action of sulphide of hydrogen—HS—by which the portion of the metallic base held in solution was precipitated in the form of sulphide. After filtration, the liquid was exposed to careful evaporation under 212°, till all the water was removed, and a viscous fluid remained. This was the glycerin. Prepared so, it is a faintly yellowish fluid, with an agreeable sweet taste; it is soluble in water, which it attracts from the air, and likewise in alcohol, but not in ether. The alkalies, and several metallic oxides and salts, more especially those which are known to deliquesce in the air, are dissolved by it to such an extent that it ranks next to water in solvent power. With acids it invariably yields acid salts. It is a very stable compound, being persistent in air; it suffers partial decomposition when slowly distilled, and passes over unchanged when a temperature of from 500° to 600° is applied; but, when subjected to a heat beyond this, it is entirely transformed into another derivative body, known as *acrolein*, acetic acid, and inflammable gases. Thrown upon live coals, or heated in contact with air, it burns with a blue flame; heated with phosphorus in a closed tube, it yields acrolein.

When largely diluted with water and mixed with yeast, after long standing at a temperature between 6[illegible] and 85°, it yields, according to Redtenbacher, a small quantity of gas and metacetonic or propionic acid —$C_6\ H_5\ O_3 = C_6\ H_8\ O_6$, minus three equivalents of water.

Dobereiner found that, by the action of spongy platinum, it was converted into an acid. Concentrated nitric acid transforms it into water, carbonic, and oxalic acids; and, by operating upon it with hydrochloric acid and binoxide of manganese, formic acid is produced by cautiously treating it with dilute sulphuric acid. Vogel states that it may be converted into glucose, which requires confirmation, for the tendency is for both to unite and form an acid salt. Pelouze found this to be the case; for on mixing one part of concentrated sulphuric acid with half a part of glycerin, much heat was developed, and glycero-sulphuric acid resulted, the formula of which was ascertained to be $C_6\ H_7\ O_5\ SO_3,\ HO\ SO_3$.

Glycerin is heavier than water, being at 59° of the density 1·28; its composition, deduced from the analyses of itself and its salts by Pelouze, is:—

			Centesimally
6 Eqs. of Carbon,	36	......	39·130
7 Eqs. of Hydrogen,	7	......	7·609
5 Eqs. of Oxygen,	40	......	43·478
1 Eq. of Water,	9	......	9·783
	92		100·000

Formula:—$C_6\ H_7\ O_5,\ HO = C_6\ H_8\ O_6$.

Until the late investigations of Berthollet it was believed that glycerin was incapable of forming neutral compounds with acids; but from these researches it is evident that such a supposition can no longer be entertained, since synthetically the above-named eminent chemist produced compounds in every respect identical with the natural fats both of animal and vegetal origin, by the union of the respective acids of such bodies with glycerin. He found that this base is capable of uniting with one, two, or three equivalents of the acids respectively, the triacid body being similar in all its properties to the natural fat of which such acid may be a component. The several compounds are prepared by heating the acid and glycerin together, during three or four days, in close vessels, at 212°; or for as many hours, at a temperature varying from 360° to about 500°, employing an excess of one or other of the constituents, according as the mono-di- or tri-acid compound is to be produced. By treating the mixture of fatty acid and glycerin with hydrochloric, sulphuric, phosphoric, or tartaric acid, in a close vessel, for some hours, at the boiling point of water, the same results are obtained. These several formations are attended with the separation of the elements of water, which, however, does not take place in proportion to the equivalents of acid which combines with the glycerin, though the analogous compounds of each of the fatty acids correspond in this respect. This disposition of the bodies will be better understood by collating the symbols of the several fats and their constituents, as in the following :—

			Stearic acid.		Glycerin.		
Monostearin,.......................	$C_{42}\ H_{42}\ O_8$	=	$C_{36}\ H_{36}\ O_4$	+	$C_6\ H_8\ O_6$	—	2 HO.
Bistearin,.......................	$C_{78}\ H_{78}\ O_{12}$	=	$2\ (C_{36}\ H_{36}\ O_4)$	+	$C_6\ H_8\ O_6$	—	2 HO.
Tri or Ter-stearin,...................	$C_{114}\ H_{114}\ O_{12}$	=	$3\ (C_{36}\ H_{36}\ O_4)$	+	$C_6\ H_8\ O_6$	—	6 HO.
			Margaric acid.				
Monomargarin,.....................	$C_{40}\ H_{40}\ O_8$	=	$C_{34}\ H_{34}\ O_4$	+	$C_6\ H_8\ O_6$	—	2 HO.
Bimargarin,.......................							
Trimargarin,.......................	$C_{108}\ H_{104}\ O_{12}$	=	$3\ (C_{34}\ H_{34}\ O_4$	+	$C_6\ H_8\ O_6$	—	6 HO.
			Oleic acid.				
Monolein,.......................	$C_{42}\ H_{40}\ O_8$	=	$C_{36}\ H_{34}\ O_4$	+	$C_6\ H_8\ O_6$	—	2 HO.
Biolein,.......................	$C_{78}\ H_{74}\ O_{12}$	=	$2\ (C_{36}\ H_{34}\ O_8)$	+	$C_6\ H_8\ O_6$	—	2 HO.
Triolein,.......................	$C_{114}\ H_{104}\ O_{12}$	=	$3\ (C_{36}\ H_{34}\ O_8)$	+	$C_6\ H_8\ O_6$	—	6 HO.

Until within the last few years, glycerin was invested only with scientific interest, and its production was of rare occurrence; now, however, it has acquired considerable repute, and is manufactured in large quantities. In medicine it is calculated to render very great services as a vehicle for exhibiting the various remedies, besides being itself a specific for many ailments. Under certain circumstances, it acts as a valuable antiseptic, and a solvent in the cure of many kinds of urinary calculi. In perfumery and cosmetics its use is daily extending, being, on account of its emollient qualities and freedom from greasiness, an admirable ingredient for soaps, pomade, hair tonic, *et cetera*. Photographers likewise have latterly employed it with success. In these and several other appliances it is likely that in a short time its consumption will be much greater than at present, although it has already been manufactured extensively.

Several modified processes are pursued to obtain it, some of which may be briefly noticed. As already stated, it was procured as a secondary product in the manufacture of lead plaster. Equal parts of powdered litharge and olive oil were mixed with water, and the mixture boiled till a plombiferous soap resulted from the combination of the oleic and other fatty acids and metallic oxide. During the ebullition, the contents of the vessel were kept stirred, and water supplied from time to time, to make up the loss by evaporation. When the yellow color of the litharge disappeared, and the mass looked white and homogeneous, the fire was removed, and the liquid portion decanted, and afterwards treated with sulphide of hydrogen, as long as any precipitation occurred. A succeeding filtration removed the metallic sulphide, and after this the liquid was evaporated at a water-bath heat, and finally in an exhausted receiver over sulphuric acid. When the evaporation is performed in contact with the air, the fluid acquires a brownish tinge. JAHN'S process is similar to the foregoing, only that the proportion of the substances is varied. Instead of equal quantities, he takes five parts of litharge and nine of olive oil, and proceeds with them as described, and boils the soap with water three successive times, decanting and mixing the three solutions together. The color is removed by filtration through animal charcoal, or by digesting the weak liquor with a mixture of animal and freshly-prepared wood or peat charcoal, filtering and concentrating in the usual way. By this course, he obtained about seven ounces of glycerin from the above quantity of materials. Glycerin can be obtained from the mother liquor of the soap factories, by adding to it a slight excess of sulphuric acid, heating the solution with carbonate of baryta, filtering, and, after the filtrate has been concentrated by evaporation, extracting the glycerin with alcohol. On distilling off the spirit, the glycerin remains. It may likewise be readily prepared by dissolving castor oil in absolute alcohol, and passing hydrochloric acid gas through the fluid. The fatty ethers are washed away by water, and the residuary fluid affords the glycerin in a state of purity on evaporation. Any adhering fatty matter is separated by digesting the liquid in ether, and decanting the latter.

CAP'S process for the manufacture of glycerin from the mother waters of the saponification of stearin with lime in the manufacture of stearic acid candles, is as follows :—The liquid drawn off from the lime-soap is reduced by evaporation in steam kettles over a naked fire; and, after ascertaining how much lime is present, by precipitating a certain bulk with oxalate of ammonia, collecting the precipitate, drying, burning, and weighing it, with the requisite precautions, the necessary quantity of sulphuric acid to combine with the lime is added, when sulphate of lime falls.

After its subsidence, the clear liquid is decanted into another receptacle, in which it is boiled out of contact with the air, and stirred at the same time by some mechanical arrangement. This ebullition expels all the volatile fatty impurities which may be present, and, consequently, the liquid loses both color and odor. As soon as the solution arrives at a density of 14° Twaddell, it is allowed to cool, when the precipitation of a further portion of sulphate of lime occurs. Should an excess of acid be present, as may be known by its action on tincture of litmus, some chalk or powdered limestone must be added fractionally till the liquid is neutral. After this the boiling is continued as before out of contact with air, during which time the contents of the vessel must be actively stirred, till the solution marks 37·5° Twaddell. The sulphate and carbonate of lime are now collected on a filter, and the filtrate reduced by evaporation, till, upon cooling, it marks 49°, care being taken to keep it well agitated during the time. If any further quantity of sulphate of lime falls, a repetition of the filtration is necessary. To remove the tinge, tho fluid is passed through washed animal charcoal or bone black, when a pure colorless solution of glycerin is obtained, marking 45°; and, by carefully concentrating it further, a fourth of its weight of water may be removed, when the residuary sirupy fluid indicates 51·2° Twaddell. According to Wilson, the product thus obtained, though superior to that manufactured by the old process, is not absolutely pure, no matter how much care is taken in conducting the operations.

A much more economical process is that introduced by Tilghmann in 1854. By this process the fatty bodies are broken up into acid and basic substances, through the agency of heat, pressure, and steam, as described at page 433, vol. i., and form separate layers in the recipient, into which the products flow from the condenser. The glycerin, which is the heavier of the two, forms the lower stratum, and the fatty acids the upper; the latter can be readily separated mechanically, and the former left devoid of any other impurity excepting water. By careful concentration, the aqueous matter may be expelled, and the product obtained of a specific gravity of 1·24, and containing only four per cent. of moisture; but, by prolonging the operation, two per cent. more of water may be removed, and the pure glycerin is left of a density = 1·260. Wilson, by injecting superheated steam into a hot solution of fat, succeeded in effecting the decomposition of the latter, and at the same time the fatty acid and glycerin are carried over into the receiver, where they form two layers, as in the preceding instance, and capable of being readily separated.

Analysis.—The analysis of glycerin demands all the expertness of the practical chemist. It may be accomplished by submitting it, or some one of its more definite and permanent salts, to combustion with oxide of copper or chromate of lead. If a salt of this base with baryta or lime be the subject, it may be mixed with the powdered oxidizing agent, introduced into the combustion tube, and burned in the usual way; but when glycerin *per se* is to be analysed, it must be inserted into small glass bulbs, the apertures of which are drawn out to a fine point, and two or three of the latter introduced into the combustion tube, placing three or four inches of the oxidizing agent between them. From five to ten grains will be sufficient for the analysis. Attention should be paid to inserting the bulbs, so that the aperture of each may open towards the sealed end of the tube, in order that the fluid may have to traverse through a longer portion, and come in contact with more of the oxidizing agent than if the bulb part was dropped in first. By this means, a more thorough oxidation of the elements is insured. The water and carbonic acid produced during the burning are severally arrested by chloride of calcium and hydrate of potassa in the usual way, and their quantity determined. When operating upon liquid substances generally, the combustion tube should be longer than when required for solid bodies, to present a greater oxidizing surface to the vapor as it passes off.

Glycerin cannot be readily detected in animal fluids, unless it be present in such quantity as will permit its being extracted and subjected to an elementary analysis; but as it is exceedingly difficult, or nearly impossible, to isolate it pure when associated with other animal matters, this method can rarely be successful. A characteristic test remains, however, whereby the presence of glycerin may be ascertained, in the peculiar bodies to which it resolves itself on being decomposed by heat. The most remarkable of these is acrolein—a substance possessing such an intense and marked odor as to render it unmistakable. When, therefore, the substance suspected as glycerin, after being deprived as far as possible of all impurities, is rapidly heated either *per se* or with a little anhydrous phosphoric acid, an acrid pungent odor, somewhat analogous to that of the wick of an extinguished candle, is evolved, and this is sufficient proof of the presence of glycerin.

GOLD.—*Or*, French; *Gold*, German; *Aurum*, Latin.—This most precious of the metals, so highly esteemed on account of its rarity, beauty, high specific gravity, non-liability to tarnish or oxidize, and consequent admirable adaptation, both as a medium of exchange, and for articles of ornament, has been known and prized from the most remote antiquity. In its pure state, it is of a rich yellow color, high metallic lustre, but nearly as soft as lead, so that it cannot be used in a state of absolute purity either for jewellery or coinage. It is the most malleable of metals, and with the single exception of platinum, it is the heaviest body in nature, being nearly twenty times the weight of its bulk in water. Gold is almost always found in the metallic state, and in this form is largely diffused over the earth; but in many localities it occurs in such minute and widely-scattered fragments, that it will not pay for working expenses. It is found in many forms—in masses, lumps, fragments or nuggets, dendritical threads, scales, dust, and infinitesimally mixed with the auriferous quartz; but almost always mechanically mixed, and not chemically, as with other metallic ores. Hence, the operations for extracting it from its deposits differ from those required by almost every other metal, in being for the most part purely mechanical. They chiefly consist in pulverization and washing—the high specific gravity of the metal greatly facilitating the latter process. But thoroughly to extract the gold, amalgamation is often resorted to—a quantity of mercury being mixed with the ore, which forms an amalgam with the gold, and is afterwards expelled by distillation. If copper and silver be present, which is generally the case, the former is removed by cupellation, and the latter by a process termed *parting*. These operations will be fully described under their proper heads. They have merely been referred to at present to explain the incidental allusions to the metallurgical department of the subject, which cannot be entirely avoided in detailing the history of the metal, and of modern gold discoveries.

Historical Notice.—From the circumstance that gold occurs in the metallic state, often mixed with the superficial soil and sands of rivers, it was probably the first of the metals known to man. Accordingly, one learns from the sacred record, that gold existed in that part of the earth's surface which was first prepared as the dwelling of the human race. Moses states, that the land of Havilah, encompassed by one of the four rivers which watered the garden of Eden, not only possessed gold, but gold of a superior quality; and Job, who is supposed to have written about 1800 years before the Christian era, alludes to the earth having *dust of gold*. With reference to the remark of Moses, that the gold of the land of Havilah was good, Mr. NAPIER of Glasgow, in a recent publication on the Ancient Workers and Artificers of Metals, justly regards it as warranting two inferences; first, that gold had been found in other localities than the one referred to; and, second, that different qualities of gold were known in the time of Moses. But as this, like the other metals, is an elementary substance, and not a compound, it follows that all gold, when pure, must be of the same quality. Hence the further inference, that the workers in metal in the time of Moses, with all the acknowledged skill of the ancients in metallurgy, were not acquainted with the method of reducing gold to a state of absolute purity. That they were acquainted with the refining of the precious metals to a certain extent, plainly appears from different passages in the Old Testament, in which familiar allusion is made to this operation; and made, too, in terms which seem to imply that the methods then adopted were in many respects similar to those now employed. Silver and gold are purified or separated from foreign ingredients by much the same processes; a knowledge of the one implies a knowledge of the other; and Job says, surely there is a mine for silver, and a place for gold, which men refine; while David compares the words of the Lord to silver tried in a *furnace of earth*, purified many times. Malachi is still more particular when, in comparing the Judge of all the earth to a refiner's fire, he says: *he shall sit as a refiner and purifier of silver, and he shall purify the sons of Levi, and cleanse them as gold and silver.* Here there is an evident allusion to the last operation required in the refining of silver—that of cupellation—during which the refiner must place himself at the furnace, and watch till the metal emits a bright flash, which indicates that the process is finished. Gold, as will be afterwards explained, is submitted to the same operation; but it requires a further treatment to free it from the silver with which it is invariably mixed to a greater or less extent; and this operation, known as *parting*, is the only process, essential to the perfect purification of gold, which does not seem to have been known to the ancients. There is, at least, no evidence that they were acquainted with this process; but rather the contrary, from the words of Moses, which indicate that gold from different sources was then believed to possess essentially different qualities; although, it is true, that the sacred historian may refer to the different states of purity in which the metal was found.

The small per centage of silver which is frequently found in gold in the native state, detracts but little from its beauty or value; and as the ancients appear to have been well acquainted with the methods of separating it from other ingredients, there is little doubt that a large proportion of their gold approached to a state of purity. On the other hand, it is frequently found combined, or mechanically mixed, with a very considerable amount of silver; and hence it may be presumed, that much of the gold in circulation among the ancients, was merely an alloy of these two metals in those proportions in which they are found in nature. This view of the subject is not only rendered probable by the frequent allusions to *fine gold*, and to gold of different qualities obtained from certain specified sources, such as the gold of Ophir, gold of Parvaim, gold from the North, *et cetera;* but it is confirmed by the fact, that the ancients had a special name for the alloy produced by the mixture. This alloy they termed *electrum*, which PLINY states to have been made artificially by mixing four parts of gold and one of silver. Now, it is worthy of notice, that this is about the mean proportion in which the admixture is found native in many auriferous localities; and hence it may be presumed, that the alloy termed electrum, for which the moderns have no distinguishing name, was formed by the ancients artificially to imitate a large proportion of the gold which was then in circulation, separated from all its native impurities, except the silver. BECKMANN, who states positively that the ancients were not acquainted with the art of separating gold and silver, affirms that they used the electrum as a peculiar metal; and NAPIER is at the pains to argue, that since they made it artificially, it could not have been considered by them a distinct metal. But BECKMANN evidently means that they regarded the mixture in the same light as brass, bronze, German silver, and other useful alloys are viewed in the present day.

On the whole, there is strong ground for believing that the ancients were unacquainted with the method of *parting* these noble metals—the difficulty arising from the fact, that both of them refuse to be oxidized in the furnace; and yet, there is a shade of doubt on the subject, which renders it peculiarly interesting to the archæologist. Nitric acid is said to have been unknown until it was discovered by the alchemists in the thirteenth century; and yet, Mr. HERAPATH, of Bristol, has lately discovered that the markings on a piece of mummy cloth were made with a solution of silver, which he concludes to have been the nitrate, or common marking ink. Indeed, there is some ground for believing that the ancient Egyptians were acquainted with both nitric and sulphuric acids, with either of which the operation of parting is performed; and in that case, they could not be ignorant of the fact that nitric acid dissolves silver, and that it is without effect upon gold. On the other hand, it is difficult to suppose, that if these things were known to the Egyptians, they should not have been known to other nations, and more especially to the Hebrews.

But whatever doubt may rest on this point, it is certain that the ancients, in later times at least, were acquainted with the method of extracting gold and silver from the ores or earths by *amalgamation*, for this process is mentioned both by VITRUVIUS and PLINY, writers who lived about the beginning of the Christian era; and, indeed, it is described by PLINY in terms which show that it was practised nearly in the same manner as at the present day. The mercury employed in this operation, merely combines with the metals in the earths with which it is mixed, and these must afterwards be separated by other processes.

Both gold and silver, more or less pure, were used by the ancients for articles of ornament and utility, as well as for money. Many of the vessels, and much of the sacred furniture of SOLOMON's magnificent temple, were made of gold. It is stated also, that in forming the tabernacle in the wilderness, gold was beat into thin plates, and cut into wires or threads to work it in the fine linen, from which it appears that the Israelites had learned from their masters, the Egyptians, the art of gold-beating—an art in which, WILKINS states, in his *Ancient Egypt*, the latter were well skilled.

Gold was also in great demand among the heathens, for the statues of their gods or idols; and some of these are mentioned by HERODOTUS and other historians as of immense magnitude. In connection with this subject, the golden calf which was made by AARON in the wilderness, has furnished a curious subject of controversy to modern commentators. With reference to this object of idolatrous worship, it is recorded that MOSES took the calf, and burned it with fire, and ground it to powder, and strewed it upon the water, and made the children of Israel drink of it. In another passage it is stated, that he stamped it, and ground it very small, even until it was as small as dust. Now, the difficulty connected with this passage, which has so much perplexed well-meaning commentators, is the fact, that gold, however strongly heated, is incapable of being reduced to powder by mere stamping or grinding. It is, as already stated, the most malleable of the metals, and is only *flattened* by stamping. Hence it has been affirmed by Dr. KITTO, on the authority of GOGUET, and reiterated by other commentators as a great discovery, that MOSES was acquainted with the wonderful powers of *natron* as a solvent of gold, and that the golden calf was either burned with natron, or was heated in the fire to accelerate the action of that solvent. Unfortunately, however, it so happens that natron or carbonate of soda has no such action upon gold as that which is ignorantly attributed to it by these writers; moreover, there is no mention of any solvent being used, or of any intention on the part of MOSES to communicate to the water with which the gold was mixed a nauseous taste, though this appears to bo the principal object of the commentators. In fact, as NAPIER justly remarks, the whole chemical or metallurgical difficulty, if any such exists, may be got over, by merely assuming that MOSES fused the gold in the fire to cast it into ingots, which were afterwards beat out into thin plates or leaves, and then would readily admit of being reduced to powder—a process which is practised at the present day to procure an impalpable gold dust employed for various purposes.

Although it can scarcely be supposed that the total amount of gold in circulation in ancient times was so great as at present, yet, from the practice of hoarding the precious metals which then prevailed, and from the limited commercial intercourse which then existed, it seems to have accumulated in some countries, and in particular circumstances, to an incredible extent. Conquerors were accustomed to carry off all the gold they could collect or extort from the subdued nations; and thus, after a series of successes, the coffers of the victorious monarch and his subjects became replenished with treasure. Hence the vast amount of the precious metals which poured into Rome from the provinces, when she ruled the world. Hence also the enormous accumulation of gold and silver which King DAVID is recorded to have collected during his lifetime for building the temple—an amount which has been estimated at not less than nine hundred million pounds sterling, being more than all that has been raised in all the mines in the known world during the last fifty years. It is scarcely possible to avoid the suspicion that some error has crept into the calculations by which this astounding result is arrived at: but still it is quite certain that immense quantities both of gold and silver were often accumulated in ancient times; and to this day no inconsiderable mystery hangs over the sources from which these treasures were derived. Any little knowledge that is possessed on this subject will be mentioned in enumerating the auriferous or gold-producing localities known at the present day.

It is probable that with the decline of the Roman Empire, the art of extracting and refining the precious metals, like other arts, became to a great extent lost in the darkness of mediæval barbarism. It was then, however, that a new art began to appear, which aimed at a still higher object, and which, however chimerical in its pursuits, struck out many important incidental discoveries, and contributed largely to prepare the way for the triumphs of modern chemistry. Any account of the history of gold would be incomplete which did not make some allusion to Alchemy—the chemistry of the middle ages—by which was elaborated, not gold indeed, but much of the apparatus and many of the principles of a science which is infinitely more important to the human race than gold itself. The object of alchemy was not the refining of the precious metals, but their multiplication, by the transmutation of the baser metals into gold and silver. This pursuit, which may be termed sordid. when viewed in the light of the motives by which it was animated, continued through long centuries of darkness to lead the philosophical world on an *ignis fatuus* chase, terminating in disappointment and misery. HERMES TRISMEGISTUS, who is said to have lived in the year of the world 2076, has generally been quoted as the oldest of the alchemists: but there can be little doubt that the writings attributed to him are entirely spurious. The next great name in the history of alchemy was GEBER the Arabian, who is supposed to have lived not later than the seventh century of the Christian era. A work on alchemy, in three books, bearing the name of this philosopher, was published at Strasburg in 1520, and shows a considerable knowledge of the chemical properties of gold. This metal was termed by the alchemists *Sol*, the sun—and silver, *Luna*, the moon. Medical preparations of gold were termed *solar*, and those of silver, *lunar* medicines. One of the chapters of the work attributed to GEBER is devoted to *The Alchemie of Sol;* and after descanting upon different means of refining and dissolving gold, the author describes several solar medicines, which are all solutions of gold in nitro-hydrochloric acid, with the addition of quicksilver or mercury, common salt or chloride of sodium, and some other saline matters. If the work be genuine, therefore—a point, however, on which considerable doubt rests—nitro-hydrochloric acid was known as *the* solvent of gold in the seventh century. It was certainly known as such not later than the fifteenth, and was termed by the alchemists *aqua regia*, or the royal solvent, from the circumstance that gold was regarded by them as the king of metals. They esteemed it, indeed, the only pure metal, and believed that all the others were merely adulterations or diseased forms of the same substance, which might be purified or revived by proper processes. Mercury and aqua regia were the principal agents which they employed. Not a few of them pretended to have discovered the secret; and some were even so disinterested as to publish the process, but in language understood only by the adepts, and which, it may be safely presumed, was rarely intelligible to themselves. In all cases, the student was directed to prepare his mind by suitable acts of piety and charity; and much religious and cabalistic jargon was mixed with their pretended recipes. From the fact that, in the present state of chemical science, the other metals, as well as gold, are believed to be elementary substances, the Editor deems it unnecessary to say that the doctrine of transmutation was founded on ignorance; but at a time when the elementary nature of the metals was unknown, the belief in their possible transmutation was natural; hence it was cherished by not a few persons of acknowledged eminence. The celebrated ROGER BACON, who flourished in the thirteenth century, was a believer in alchemy, and published a work on the subject. VAN HELMONT acknowledges his belief in the making of gold and silver, though he does not degrade himself, like too many of his contemporaries, by professing to have discovered the secret. BERGMAN, in summing up the evidence for and against the possibility and probability of transmutation, arrives at the conclusion that, unless all historical evidence be rejected, some of the accounts given are entitled to confidence. Even the great Lord BACON has been arraigned as a believer in alchemy, though he rather urges the possibility than the probability of transmutation—a view of the subject so far from meriting ridicule that, in the state of chemical science in his day, it would have been unphilosophical to hold a different opinion. That BOYLE was a sceptic on the subject is well known; but it is less generally known, and in fact it has only lately come to light, that in the ranks of the alchemists must now be enrolled the illustrious name of Sir ISAAC NEWTON. This startling fact is a recent discovery, published for the first time in the last edition of Sir DAVID BREWSTER'S life of that philosopher. It is now known that he was absorbed in this pursuit for years; and that the intense eagerness with which he prosecuted this object accounts, to a great extent, for the apparent indifference which he showed in so long delaying to publish some of his greatest discoveries. Associated with such an array of great names, and more especially with the last, the alchemists are not to be contemned or derided as mere dreamers and visionaries; the pursuit of the object which they had in view was as natural as their belief in the possibility of its attainment was warranted by the knowledge of the composition of matter then existing; but that which excites a just indignation, which constitutes a fair subject for ridicule, and stamps with infamy many of the professors of the art, is the mixture of fraud, pretension, and hypocrisy, which appears in their writings. It is these unworthy professors that have brought contempt on a pursuit that was prosecuted by many good and great men; and which, however fruitless as regards the immediate object in view, elicited many important facts of which science at the present day reaps the full benefit. The history of alchemy—so replete with empiricism and pretension—teaches also the gratifying fact, that not only has the philosophical world advanced in knowledge, but in candor, in honesty, and in moral dignity.

The further history of gold, which has assumed a profound interest in modern times, and demands therefore a larger space than is usually devoted to historical notices in this work, will be given in connection with the sources or localities from which it is chiefly derived.

SOURCES.—With the single exception of iron, gold is more generally distributed than any other metal; but for the most part it occurs in such minute quantities, as either to escape notice, or, as already remarked, not to repay the cost of extraction. On the other hand, many localities in different quarters of the globe, and especially, of late years, portions of California and Australia, have proved splendid exceptions. The principal matrix of gold is quartz rock, and this rock is commonly a vein of greater or less thickness, intersecting beds of granite. The chief sources, however, from which gold is obtained, are the various alluvial deposits, consisting of sand and gravel, produced by the disintegration of silicious, granitic, and other igneous and metamorphic rocks, and which have been transported by the agency of water from the mountainous districts. In these beds it is invariably found in the metallic state, but is never quite pure; it usually contains a certain proportion of silver, and not unfrequently iron, copper, and small quantities of several other metals.

It is difficult, if not impossible, to ascertain the precise localities from which were procured the very considerable quantities of gold that indisputably existed in the earlier ages of the world. There is no doubt that many regions, now exhausted, would formerly yield large supplies of this precious metal. The name of the place which figures most prominently in the Old Testament writings, and which has reappeared as the designation of certain auriferous localities, in modern times, is the land of Ophir. This name occurs in the ancient book of JOB, and is frequently alluded to afterwards in the Jewish history. It seems to have been the great source of gold in those days—the California or Australia of the ancient world; but in what country, or even in what quarter of the globe it was situated, is a problem not yet solved. It is certain that the Hebrews traded with it from the time of DAVID to that of JEHOSAPHAT, and some have placed it in an island in the Red Sea; but this is inconsistent with the recorded fact, that SOLOMON'S fleet took up three years in their voyage to Ophir, and brought home not only gold, but apes, peacocks, spices, ivory, ebony, and almug-trees. Accordingly, others have removed it to Zanguebar, on the South-east coast of Africa; others have placed it about Guinea; some at Carthage; some have removed it to the East Indies; and others, still more fancifully, to Peru, or some other place in America. The only conclusion which may be safely drawn from this immense variety of conflicting conjectures is, that the question remains involved in uncertainty, although the most general and best supported opinion is that which identifies the ancient Ophir with the region of the modern Zanguebar.

Herodotus states that the people living near the source of the Indus, obtained a large quantity of gold from the eastern border of the great Bactriana, and the desert steppes of Cobi; and he also refers to productive mines in the North, the remains of which, on the South-eastern borders of the Ural mountains, are described by Pallas in his Travels, and were likewise visited by Lepechin and Gmelin. These ruined mines, which have all the marks of a very remote antiquity, are supposed to have been the work of a nomadic people, in all probability the Scythians. It is evident that much gold was produced in ancient times from the mines of Nubia and Ethiopia, which, like those of the Uralian chain, produced a copper-yielding gold. Belzoni discovered that a very extensive tract had been worked in the Sahara mountains, and from these sources the Pharaohs are supposed to have derived their wealth. Mr. Jacob, from a very close examination of the subject, is led to infer that not less than six million pounds sterling of the precious metal must have been produced annually from these mines.

There were rich silver mines in Attica; gold mines in Thrace, and in the island of Thasus. Thessaly produced ores which were rich in gold; and Epirus, rich silver mines. From these sources the Athenians drew their wealth.

The Romans obtained their treasures from various sources, besides the conquered provinces—from Upper Italy, the province of Aosta, the Noric Alps, Illyria. From this district, at one period, gold was abundantly obtained—partly in large grains on the surface, and partly in mines, so pure that an eighth part only was lost in the processes of smelting and refining. Its great quantity caused a decrease of one-third in the price through all Italy, and induced the proprietors to employ fewer workmen in order to raise the value. The Tarbelli, a people at the foot of the Pyrenees, also streamed extensively for gold.

It is stated on the authority of tradition, that when the Phœnicians visited Spain, they found silver in such abundance, that they not only loaded their ships to the water's edge, but made their common utensils, and even anchors, of this metal—a statement which harmonizes with the representations given by the Spanish discoverers of Peru. But whether this account be exaggerated or not, it is certain that the Phœnicians lost no time in taking possession of the country, and forming colonies in the present Andalusia. Now, it is known that Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias. The Tagus and some other streams of that country were said to roll over golden sands; and there is little doubt, that when colonized by an active commercial people like the Phœnicians, its mineral wealth would be developed, and would contribute largely to the supply of the precious metals in the ancient world.

It is affirmed, that the Romans extracted gold from the quartz lodes in Transylvania, and also at the Ofogan in Caermarthenshire in this island, during their occupation under Trajan. It is probable, however, that but little would be obtained from these sources; and not much further is known of the ancient gold workings.

The principal workings known at the present day are those of Australia, in the Southern hemisphere; of California, Mexico, and the Appalachian mountains, in North America; Brazil, Peru, and Chili, in South America; Kordofan and Sofala in Africa; the Ural mountains in Siberia; and Hungary in Europe. Gold is found, however, in smaller quantities in various other places; and the Editor will now briefly indicate the various localities in which it is known to exist, beginning with Europe, and concluding with the latest discoveries in Australia.

Europe.—There are probably few countries without traditions of gold, and these have not been wanting in the British Islands, which have furnished from time to time small quantities, although seldom in sufficient amount to be equivalent to the cost of procuring it. Specimens are occasionally found in Wales, in the Cornish stream-works, and in different parts of Devonshire: where mining operations were recently undertaken, but not with remunerative success. In Scotland, it occurs at Leadhills and Cumberhead in Lanarkshire, and Glen Turrit in Perthshire, but only in very small quantities; although in the time of Queen Elizabeth, extensive washings for gold were carried on in the alluvial soil of Leadhills. In the county of Wicklow, in Ireland, a considerable quantity of native gold was discovered towards the close of the last century, disseminated in a quartzose and ferruginous sand. This gold was chiefly found in *pepitas* or solid pieces, one of which weighed twenty-two ounces; and so promising was the supply, that the peasantry in the neighborhood of Ballinavalley river actually gathered in the course of two months an amount of gold, for which ten thousand pounds sterling were paid. The extraction was then undertaken by Government; but the supply was soon exhausted, for during the two years that the mines were in operation, only nine hundred and forty-five ounces were obtained, which did not pay the necessary expenses, and the works were abandoned.

In France, the Rhone, and other rivers, present auriferous sands, but there are no workable mines in that country. It is probable that the deposits have been exhausted, like those of Spain, which were anciently rich and valuable, but are now neglected. So with the sands of the Danube, and many other European rivers, which still possess gold in small quantities, but rarely worth the expense of washing. In the valley of the Rhine, between Basle and Mannheim, for example, gold occurs in flakes mixed with titaniferous iron; but so minute are the spangles, that it takes from eleven hundred to fourteen hundred of them to weigh a grain, troy. There are also auriferous sands in some rivers in Switzerland, such as the Reuss and the Aar.

In Sweden, there is a mine at Edefors in Smoland, where the gold occurs native, and also in auriferous pyrites. In Germany, no mine of gold has been worked, except in the territory of Salzburg, amid the chain of mountains which separates the Tyrol and Carinthia. In Piedmont, there are veins of auriferous pyrites in the gneiss rocks at the foot of Monte Rosa; and these, although they do not contain ten or eleven grains in a hundredweight of the ore, are stated to have long defrayed the expense of working them.

But the only gold mines of any importance in Europe, are those of Hungary and Transylvania; and these are not less remarkable for their position, than for the peculiar metals with which the gold is associated. The principal mines are those of Hungary, in which the operations are carried on in four distinct localities; first, at Königsberg, where the native gold is disseminated in ores of sulphide of silver, which occur in veins and small masses in a decomposing felspar rock, constituting a portion of the trachytic formation; second, at Borsan, Schemnitz; and third, at Felsobanya, in both of which the ores likewise consist of auriferous sulphide of silver; occurring, however, in veins of sienite and greenstone porphyry; fourth, and lastly, at Telkebanya, to the south of Kaschaic, where the gold is extracted from a deposit of auriferous pyrites, amid trap-rocks of the most recent formation. The Hungarian gold mines do not appear to have been worked before the eighth century. In Transylvania, the gold occurs at different places in veins of carious quartz, ferriferous limestone, heavy spar, fluor spar, and sulphide of silver. These veins are often of great magnitude, averaging from six to ten, and sometimes extending to forty yards in thickness. In the mine of Kapnik, the gold is associated with orpiment in granite, and in those of Offenbanya, Nagy-Ag, and Zalatna with tellurium, in a sienitic rock. The annual produce of Hungary is stated at two thousand eight hundred and ten pounds' weight, and valued at one hundred and seventy-six thousand pounds sterling.

It may be added, that the mines of Reichenstein, in Silesia, which had been abandoned for more than five centuries, have been recently opened with advantage, in consequence of the application, on a large scale, of a method invented by Professor PLATTNER, for separating gold from the waste of arsenical pyrites, which will be described afterwards.

Asia.—The gold mines of Russia, which are the most considerable in the old world, must come under the head of Asia, as they are situated partly on the eastern flank of the Ural mountains, and partly in the districts of Tomsk and Yeniseik in central Siberia. The Ural mines, including those of Berezovsk, near Ekaterinburg, extend through five or six degrees of latitude. Here there are deposits of partially decomposed auriferous pyrites disseminated in veins of quartz; and from these veins the valuable material is extracted by vertical shafts and lateral galleries. Generally, however, the gold is found associated with other metals, as platinum and palladium, in fragments or debris of auriferous rocks, mixed or disseminated at some yards' depth in an argillaceous loam.

In the days of Pallas, the gold alluvia of Russia were supposed to exist only near Ekaterinburg; but, in the reigns of Paul and Alexander, they were found to extend through several degrees to the North and South of that locality. It was only in the reign of NICHOLAS that portions of the great eastern regions of Siberia were found to be highly auriferous. In these districts the ground rises into low ridges, similarly constructed to those of the Ural, and like them trending from north to south. They are offsets from the great east and west chain of the Altai, which separates Siberia from China. The amount of gold which is now extracted from these remote deposits far exceeds that obtained from the Ural, although, in the latter, sands of superior richness were discovered in 1842. This discovery was made by the removal of certain old buildings in which the washing operations had been carried on. Under the corner of one of the buildings, at the depth of three yards, a mass of gold was dug up weighing about eighty pounds English. This mass was placed in the collection of the Corps des Mines at St. Petersburg. The discovery of the rich sands was made at the same time; but in the Ural districts, the gold is not usually found in large lumps. It is commonly obtained in very small fragments, which are separated by washing; and the yield seldom exceeds thirty-six grains of gold per ton-weight of soil. In the Altai auriferous district, which is represented to be as large as France, not only is the gold found mixed with sand and gravel on the surface, but considerable quantities are extracted by pulverizing the rocks. It is a remarkable fact that, not many years ago, the gold obtained from this distant region did not amount to a third part of that which the Ural district produced, whereas, in 1843, the Eastern tract yielded considerably upwards of two millions and a quarter sterling, and the Ural little more than half a million, raising the total produce of the Russian empire to near three millions sterling. It now amounts to about four millions. In the century previous to 1841, the mines of Berezovsk yielded about twenty-four thousand five hundred pounds avoirdupois of the precious metals.

Little or no gold comes into Europe from other parts of Asia, because, as Dr. Ure justly remarks, its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal. It is evident, however, from the quantities existing in the East, that it must be extracted in considerable amount from various sources. It is found in the rivers of Syria and other parts of Asia Minor. The Pactolus, a small river of Lydia, is said to have rolled over golden sands, which were supposed to have constituted the origin of the proverbial wealth of Crœsus. Numerous gold mines are known to exist on the Cailas mountains in the Oundes, a province of Little Thibet, where the gold is found in quartz veins, which traverse a very crumbling reddish granite. It is met with also in the peninsula of Hindostan, and in the islands of the Eastern Archipelago; and it cannot be doubted that considerable quantities are found in Japan and China.

Africa.—It is now the general opinion that the land of Ophir, so frequently mentioned in the Old Testament, was in Africa, which still presents in one part a territory known as the Gold Coast, implying by its very name the existence of the precious metal in this quarter of the globe. The territory so called, from which large quantities of this metal were formerly exported, lies on the west coast; but the land of Ophir is supposed to have been on the East coast, opposite Madagascar, where a certain amount of gold is still collected. But the principal supplies of this metal are now found at Kordofan, between Darfur and Abyssinia, known to the ancients as Ethiopia, and the western region extending south from the river Senegal to the Cape of Palms, near the Gold Coast. In these districts the gold occurs in spangles, chiefly near the surface of the earth, in the beds of rivers and rivulets, and always in a ferruginous earth. The gold which is brought from Africa is always in dust, showing that the metal is obtained by washing the alluvial soils. Although this division of the globe is supposed to have been the source of the greater portion of the gold possessed by the ancients, yet the whole supply now obtained from that continent is not estimated at more than five thousand pounds annually.

South America.—Brazil furnishes the greatest part of the gold which is brought into the market from South America, and was once the principal gold region of the new world; but its mines and auriferous sands seem to be nearly exhausted. The greatest quantity of gold was obtained from Brazil between the years 1753 and 1763, and since that time it has always been on the decrease. It was in the valley of the Mandi, a branch of the Rio Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682; but they have since been found widely extended at the foot of the great mountain chain which runs parallel with the coast from the fifth to the thirtieth degree of south latitude. The precious metal is found in nearly all the rivers which form the upper branches of the Francisco, Araguay, Tocantins, and Guaporè; but the largest proportion is found in the affluents of the Francisco. The rock in these localities consists of primitive granite, inclining to gneiss; and the soil, which is of a red, ferruginous character, often extends to a considerable depth. It is from this soil that the gold is extracted by washing. Indeed the veins containing the metal are seldom worked. The most numerous washings are established near Villa Rica, in the environs of Cocäes, where the gold occurs either mingled with the sands of the river, or in the alluvial valley deposits. The pepitas occur in various forms, often adhering to micaceous specular iron. In the province of Minas Geräes, the gold is extracted both by the excavation of veins and by the washing of alluvial deposits.

This metal is likewise found in many other parts of South America, on both sides of the great chain of mountains which runs parallel with the Western coast. Peru is richer in silver than in gold ores, but in some parts gold is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. All the gold furnished by Columbia, comprehending New Grenada and Venezuela, is the product of washings established in alluvial grounds. But Brazil is the principal gold region of the South American continent.

North America.—More gold is now produced in the vast continent of North America than in any other part of the world. In this respect it has now taken the place which formerly belonged to South America, while the latter has sunk into comparative unproductiveness, less perhaps from the absolute exhaustion of the auriferous soils, than from the want of the capital and enterprise to work them successfully. North America was a gold-producing continent long before the discovery of the Californian treasures; but for many years, the only source of this precious metal in that quarter of the globe was the argentiferous veins of Mexico, from which it was extracted along with the silver, as in the Peru mines of South America. At a later period, however, an extensive gold region was discovered in the United States, extending along the Eastern slope of the Appalachian mountains, from the river Rappahannock in Virginia Southwards to the river Coosa, an affluent to the Alabama, which flows into the Gulf of Mexico. The metal is found in less quantity Northward along the same mountainous range to the State of Maine, and even extending into Canada, where a search for profitable workings has lately been prosecuted with some vigor. The existence of spangles and pepitas of gold, in several rivers of the East of Canada, has been fully established; and at the Great Exhibition honorable mention was made of the Chaudière Mining Company, who exhibited pepitas of native gold, collected in the washing of those streams. But the States of Virginia, North and South Carolina, and Georgia, afford the most productive deposits. In these, as in those of Brazil and Columbia, the auriferous ores are chiefly pyritical; much of the gold is extracted by amalgamation, after stamping under water.

But all preceding gold discoveries in America, or in any other part of the world, were eclipsed by those that have been made within the last few years in California and Australia. These recent discoveries have produced quite a revolution in the annual production of gold, the effects of which, though already powerfully felt in the new impulse given to emigration and commerce, are only beginning to be developed, and must produce the most important results in the future history of the world. This may be inferred from the fact, that the gatherings of the precious metal, reckoning the average produce of all parts of the new and old world for a series of years previous to 1847, did not amount to the annual value of five millions sterling, whereas the amount now exceeds thirty millions per annum.

The first of these recent discoveries was made in 1847, when California, a hitherto-neglected and little-known region, lying at the most remote South-western limit of North America, rose into sudden importance, as the El Dorado of the new world. The gold region, properly so called, occupies the Northern part of California, commencing near the mouth of the Sacramento river, in lat. 39° north, and long. 122½° west, to the north-east of the bay and town of San Francisco, from which it extends south and north. At this point two rivers unite and discharge themselves into the sea—the Sacramento flowing from the North, along a valley formed by mountain ranges, and the San Joaquim, flowing from the South, along a similar valley, enclosed on one side by the Rocky Mountains, and on the other by the mountainous ridge which protects the Western coast. It was on the property of an intelligent Swiss emigrant, Captain Suter, who had become a wealthy settler on the banks of the Sacramento, that the first traces of gold were discovered in September, 1847. This happened in the course of the erection of saw-mills on the estate, when Mr. Marshall, the contractor for the building of these, observed glittering particles in the sand of the mill-race, which were ascertained to be gold; and on making further researches, it was found that the precious metal was very extensively diffused in the bed of the stream. The discovery soon became known to the work-people, by whom the intelligence was conveyed to San Francisco, and in no long time, the whole population of the little town, and the scattered and scanty settlers in the neighborhood, abandoned their dwellings and occupations to engage in the exciting search. The supply exceeded the most exaggerated accounts that had been given; new and richer localities were discovered; the gold was found in the beds of various streams flowing into the Sacramento; in the mud of the river itself; in the channels of old water-courses, and along the sides of the hills. The intelligence rapidly spread to the neighboring countries—to Mexico, to South America, to the United States, and thence to Europe. People began to flock from all quarters to the once neglected, but now coveted region; it became, in a few short months, the scene of a considerable population, instead of a few scattered tribes of Indians; miners or diggers in parties spread themselves over the face of the country; and San Francisco, from a mere village, grew up into a place of wealth, importance, and stirring activity. It was at first very generally thought that the supply would soon fail, but this anticipation has proved to be unfounded; and while, on the one hand, the amount of the precious metal disseminated in the rocks and soil appears to be almost inexhaustible—on the other hand, the constant increase in the number of miners, combined with the improved apparatus and methods of working, seems to have hitherto resulted in a steadily increasing annual produce, until within the last few years, when it seems to have been nearly stationary.

Professor BLAKE, who minutely examined the auriferous regions of California, states that, with the exception of the diluvial strata, the whole geological formation of the Sierra range, through which flow the principal rivers, consists of igneous and metamorphic rocks. The former are mostly porphyritic in the lower hills, whilst higher up trachytic rocks are more frequently met with. The metamorphic rocks consist of micaceous schists, slates both talcose and micaceous, metamorphic sandstones and limestones, with occasional beds of conglomerate. In that part of the country which he examined, the extent of the diluvial deposits was commensurate, or nearly so, with that of the gold-bearing region. They are found in a belt of land from thirty to sixty miles broad, and running parallel with the axis of the range. These diluvial deposits are met with towards the lower hills of the Sierra, extending frequently some miles into the plain. The elements of which they are composed differ considerably in various localities, although there are many points of resemblance through the whole series. In the lower valleys and flats, between the ranges of the lower hills, they appear to consist of beds of gravel, containing occasional boulders of quartz and the harder rocks. On the elevated flats, higher up in the mountains, the surface of these deposits is generally covered by a reddish loam, mixed with small gravel; whilst, reposing on the bed rock, and a few inches above it, is found a stratum containing large boulders and gravel, the boulders being principally quartz. At other points, the whole series consists of conglomerates and soft friable sandstone. Where the deposits are found extending over a large surface on the elevated flats, gold is always met with, generally diffused through the gravel immediately above the rock on which they rest, which yields from fifteen to forty cents to the hundred pounds of earth. There are parts where acres of these deposits have been turned up, in which the gravel never contains less than fifteen cents to the hundred pounds, and generally more. In the valleys in the lower hills, and even on the plains to the west of them, where they are extended over vast tracts of country, these deposits are still auriferous, the gold being very generally diffused, and found in greater quantities the deeper they are worked; but sometimes they will not pay for working, owing to the distance from water. In one place, where water could be readily obtained, a portion of these deposits, situated to the west of the lower hills, was found to yield from five to thirty cents to one hundred pounds of earth, through an extent of one hundred and fifty acres, the soil being found richer the deeper it was worked.

At a spot which was appropriately named Mount Ophir, the auriferous soil was described as soft clay and slate, saturated with gold in small particles and large lumps. This treasure was found from ten to thirty feet below the surface, and seven Mexicans, who made the discovery, and kept their secret eight days, made in that short time two hundred and seventeen thousand dollars. Other searchers, from a shaft twenty feet deep, obtained the soft clayey slate in buckets, and found from eight to twelve dollars' worth of gold in each bucket. In many cases considerable nuggets are met with, but no accounts speak of very large masses of gold having been found in California. The total produce from this region, down to the end of 1855, was estimated at sixty-four million pounds sterling; and, latterly, it has averaged about fourteen million pounds per annum.

Australia.—The world-wide excitement created by the gold discoveries in California had scarcely subsided, when another auriferous region was developed in the British dominions at the antipodes, which promises to prove not less productive. The Californian treasures were discovered in September, 1847; and in the spring of 1851 the long-concealed wealth of Eastern Australia was first announced to the world. It is remarkable that this second discovery was not made sooner; for so early as in 1841, the Rev. W. B. CLARKE, in examining the geological structure of the Blue Mountains of Eastern Australia, was attracted by the plutonic and metamorphic character of the axis of the range, and by the presence of gold in the quartzites, and in the detrital accumulations derived from the axial formations. This gentleman, a native geologist, had found evidence of the existence of gold within sixty and eighty miles of Sydney, and had affirmed his belief that the Blue Mountains would at some time prove to be auriferous. Again, in 1845, Sir **Roderick Murchison** expressed the same conviction, when he compared the Eastern chain of Australian mountains with the Ural; and in 1846 he even recommended the unemployed Cornish tin miners to emigrate to New South Wales, and dig for gold in the debris and drift of the Australian cordilleras. His writings and remarks on this subject were not entirely without effect, for in 1847 he received letters from speculators in Sydney and Adelaide, accompanied with specimens of gold, which they had sought and obtained, in consequence of his suggestions; and shortly afterwards he even wrote to Earl **Grey**, informing him that his anticipations were about to be realized in a manner which might operate a great change in the colony.

The discovery was at length made through the instrumentality of a gentleman named **Hargraves**, who had recently returned from California, and had then occupied himself for two months in exploring a considerable extent of country in Australia. On the third of April, 1851, this gentleman addressed a letter to the Colonial Secretary, stating that he had prosecuted his speculation to a successful issue, and offering, for the sum of five hundred pounds, to point out to the officers of Government the localities in which he had discovered gold. To this proposal the Secretary replied that he was not authorized to make a blind bargain, but that if Mr. **Hargraves** thought proper to trust to the liberality of the Government, he might rely on being rewarded in proportion to the value of the discovery. Accordingly, on the thirtieth April, Mr. **Hargraves** addressed another letter to the Colonial Secretary, expressing his willingness to leave the remuneration of his discovery to the liberal consideration of the Government, and naming the localities from which he had obtained specimens of the precious metal. These were at Summer Hill Creek, and other places near Bathurst, which is situated about a hundred and fifty miles west of Sydney, New South Wales.

Scarcely had this communication been made to Government, when the discovery became generally known, through some persons who had been employed under the directions of Mr. **Hargraves**. The fact was divulged that on the eighth of May these persons had obtained several ounces of gold at Summer Hill Creek; and on the thirteenth of the same month great excitement was created by the report that a solid piece, weighing thirteen ounces, had been found. This, on inquiry, proved to be correct, and hundreds of persons immediately left their accustomed avocations, and started for the *diggings*, as they were now called. The excitement rapidly extended, and on the nineteenth of May four hundred persons were congregated at Summer Hill Creek; on the twenty-ninth, one thousand; and on the fifth June their numbers had increased to fifteen hundred.

The Government now lost no time in adopting the necessary measures for maintaining order. A proclamation was issued, dated twenty-second May, 1851, declaring that, from and after the first of June, all persons digging for gold without a license would be proceeded against; and authorising the crown commissioners to grant such licenses for a fee of thirty shillings per month. A force was appointed for the purpose of collecting the fees, and strong detachments of police were stationed along the principal roads leading to the gold fields. At the same time, Mr. **Hargraves** and the Government geological surveyor, Mr. **Stutchbury**, with whom Mr. **Clarke** was afterwards associated, were ordered to make an immediate survey of the various localities in which it appeared probable that gold would be found.

But the spirit of enterprise was now awakened in the diggers themselves, and soon conducted them to new and richer deposits of the precious metal. From Summer Hill Creek, to which the name of Ophir had been given, a great emigration took place to the Turon River—another of the localities first pointed out by Mr. **Hargraves**, and lying a little to the Northward of Summer Hill; and in the month of December the number of diggers on the Turon amounted to six thousand. Subsequently, gold was discovered at various other places in Bathurst, as well as in the adjoining counties of Wellington, Roxburgh, Georgiana, and Ashburnam. Latterly it was found so far South as St. Vincent, and ultimately over the entire mountainous range of New South Wales, extending from 27° to 37° of south latitude; but more abundantly in the Southern portion of the province.

But the progress of discovery did not confine itself to New South Wales. It still advanced to the South; and in a despatch, dated twenty-fifth August, 1851, Lieutenant-Governor **Latrobe** communicated to Earl **Grey**, that large deposits had been found in the colony of Victoria. The three localities first named were: Clune's Diggings, about forty miles from Melbourne, where the gold was found in an alluvial deposit, consisting chiefly of quartz gravel; at Buninyong, near Ballarat, about eighty miles from Melbourne or fifty from Geelong, where the gold was sometimes imbedded in compact quartz; and Deep Creek, only nineteen miles from Melbourne, where the precious metal was found to exist in connection with slate rock. It was afterwards discovered almost in the neighborhood of Geelong, and likewise at a place called Mount Disappointment, about thirty miles to the North-east of Melbourne; and, finally, the people of that town began to break up the streets, which had been macadamized with quartz pebbles obtained from the gold districts.

The excitement created in the colony of Victoria by these discoveries surpassed even that which had taken place at Sydney. The whole neighboring population were moving towards the gold regions; Melbourne and Geelong were almost emptied of their inhabitants; and it was found impossible to retain the services of the Government employés, without an addition to their salaries of—first, twenty-five, and, subsequently, fifty per cent. Even the superior class of farmers and tradesmen were drawn into the vortex, partly from sharing in the general mania, and partly because, when deprived of their laborers and assistants, they had no alternative but the diggings. For some time Ballarat was the great source of attraction, and the stories told of its productiveness were almost incredible. Eight feet square of that auriferous soil was deemed a fortune. One man had found fifteen hundred pounds' worth of gold in one week—another man a thousand. A party of three men had met with twenty pounds' weight in one day!

But even Ballarat was shortly surpassed by a fresh gold-field discovered in the Mount Alexander range, still further to the north, about ninety miles from Melbourne. This was found to exceed in richness all the diggings previously discovered. So great were the attractions of this new field, that the number of diggers at Ballarat, which had risen to six thousand, was quickly reduced to one thousand six hundred, while the number at Mount Alexander rose to twenty thousand. This was the climax of the excitement created by the gold discoveries. The whole structure of Australian society became for a period completely disorganized. Subsequently the precious metal was discovered at various other localities, and the supply was so far increased that gold arrived at the seaports at the rate of two tons per week. The excitement has now subsided; and no new localities have been reported, yielding the same fabulous treasures as Ballarat and Mount Alexander, when first discovered; but various new sources have been opened up, and a map of the country, exhibiting the gold regions, seems to indicate the precious metal as disseminated in greater or less abundance over the whole of the mountainous range which extends through New South Wales and Victoria. The field of operations, therefore, continues to extend; improved machinery is brought into action; and the consequence is, that, while less excitement exists, there is more of steady productive labor, and the aggregate supply of the precious metal has continued to increase yearly till the present time, when it seems to have attained nearly its maximum, at thirteen millions per annum. It is expected, however, that when the labors of the large numbers now employed in deep sinking and in quartz mining are brought to a profitable consummation, the yield, if not greatly increased, will at least be permanently sustained. Further details on this subject, and the produce of the principal mines and auriferous regions throughout the world, will be given at the close of the present article, under the head of Statistics.

ORIGIN AND POSITION OF THE GOLD DEPOSITS.—The matrix of the gold in Australia, as in other auriferous regions, is quartz. The general character of the soil may be inferred from the description given of the Turon and Summer Hill Creek districts, where the gold was first found, and where, according to Mr. STUTCHBURY, the Government geologist, the whole area may be considered as schistose, principally clay-slate, accompanied by nearly all the other varieties of slate rocks, and also by a large amount of quartzites in veins or lodes, parallel to the stroke of the schist. In this district, the trend of all the waterways, or *creeks*, in which the gold is chiefly found, is into the Macquarrie river. The quartz is amorphous, very rarely crystallized; and in the neighborhood of the gold-yielding localities, it is accompanied by titaniferous iron, both crystallized and in loose grains. Many instances occur in which the quartz remains attached, and interlaced by the gold, as also the iron. It is a fact worth recording, that no gold has been found in Australia, without the iron sand—incorrectly termed emery—accompanying it.

Gold in small quantities has been found on the summits and upon the flanks of the mountain ranges; but, with few exceptions, it bears evidence of abrasion; and the larger produce in every instance has been found in the lower levels. Assuming that the auriferous deposits originated in the quartz rock, says Mr. STUTCHBURY, there is no difficulty in accounting for its presence most abundantly in the various gullies and creeks so numerous in this remarkably broken country. The schistose rocks, so readily acted upon by the atmosphere, constantly disintegrating and exposing the quartzose dykes, leave them unsupported; and gravitating downwards, the largest blocks are crushed and crumbled in their onward course, letting loose the tenacious gold in large or small portions, which, in obedience to their gravity, and the force of the impelling torrents, roll on until they are arrested for a time in hollows, or the cleavage fissures of the slaty rocks, or quietly deposited in the sand and mud, as the case may be, by the cessation of the flood, until they are again removed by the repetition of similar causes; or they may remain for ages undisturbed, by the torrents taking another course, of which there are so many instances, leaving ancient bars of shingle debris now covered by accumulated soil. It therefore follows that gold, even if it be of the earliest geological origin, may and will be accumulating in the lower valleys, as long as mountains waste and valleys exist for its reception.

It has been asserted, however, by some writers, that the gold, instead of being torn out by the waters from the veins and primitive rocks which they traverse, actually belongs to the grounds washed by the waters as they glide along. In proof of this, it has been urged that gold is almost always found among the sands of rivers only in a very circumscribed space, and that on ascending these rivers, their sands cease to afford gold, whereas, did this metal come from the rocks above, it should be found more abundantly near the source of the rivers. Thus, the late Dr. URE remarks, that the Orco contains no gold except from Pont to its junction with the Po. In like manner, the Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake where its course is necessarily slackened, and into which whatsoever it carried down from the mountains must have been deposited. The Rhine gives more gold near Strasburg, than near Basle, though the latter be much closer to the mountains; and the sands of the Danube contain no gold, so long as the river runs in a mountainous region—that is, from the frontiers of the Bishoprick of Passau to Efferding—but they become auriferous in the plains below. The same thing is stated of the Ems, and other rivers; and it must be admitted that the opinion, to which it naturally leads, rests upon very strong grounds, and is supported by some of the highest authorities.

Though gold is frequently found at the surface, mixed with the sands of rivers, yet the auriferous stratum is often buried at considerable depths, and hence the necessity of opening *pits* or *diggings*. Figs. 204 and 205 will afford some idea of the Australian gold-field strata. Tho latter represents what the diggers call a surface gullet, the gold being met with at about sixteen feet from the surface; the former is a section of a deep gullet, in which the auriferous ore is at a depth of thirty-six feet. The corresponding letters, in both sections, indicate similar strata; *a*, black loam and quartz; *b*, white loam, clay, and sand; *c*, brown clay; *d*, gold layer; *e*, yellowish-brown rock; *ff*, quartz in a concrete mass; *g*, stratum of sand; *h*, common clay. The auriferous ore earth is generally of a light color, or largely mixed with quartz pebbles, very tenacious and difficult to wash. It lies upon a yellowish brown rock, of a rotten texture, known as fixed slate, whilst higher up, above the gold, the strata present igneous features.

Fig. 204.

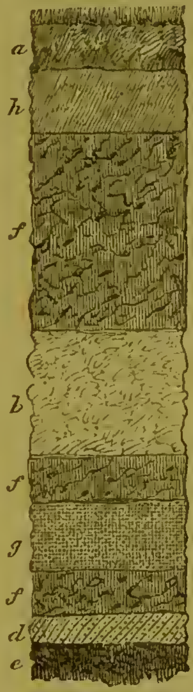
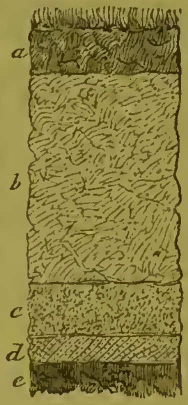


Fig. 205.



Probable abundance of Gold at great depths.—The probability that gold exists in almost unlimited amount at greater depths than have been yet explored for this metal, is thus argued by Mr. W. BRIDGES ADAMS: Quartz rock is the matrix of gold, and quartz rock is commonly a vein of greater or less thickness intersecting the beds of granite. In this quartz the metallic gold is distributed, in particles of more or less fineness, and sometimes it is found in lumps. If the granite be supposed to have been once in a state of fusion, and cracked in cooling, forcing up into the fissures the liquid quartz containing the gold, it seems more than probable that the greater part of the molten gold would settle to the bottom of the fluid mass, as the metal precipitates in an iron furnace, beneath the slag. The fragments that are found in rivers and alluvial ground have probably been thrown out by subsequent volcanic action. The spangle-gold, the nuggets, the gold-dust, and other varieties, seem to confirm this; and probably, in depths of alluvion greater than have yet been penetrated, large golden fragments will be discovered, just as the lugest pieces of rock aro found undermost in the beds of mountain torrents. If this theory be correct, it is quite within possibility that the gold-hunters, who havo as yet explored but a small portion of the earth's surface, may light upon larger deposits—may yet penetrate to some mass larger than the famed native iron of Santiago del Estero, or a quartz vein gradually changing into the pure metal. The lighter fragments washed to the edges by the stream have alone been gathered; they are but indications of the larger masses that lie in deposit below; and it may be predicted that wherever gold has been superficially gathered at any period, it will be found in larger masses at some greater depth.

If there be any truth in this ingenious conjecture, it will soon be brought to the test of experiment by the operations now in progress in Australia, with a view to deep sinking and quartz mining on a very extensive scale.

METHOD OF EXAMINING AURIFEROUS DEPOSITS.—As a general rule, the rocks in the district to be examined for gold should be either granitic, porphyritic, or quartzose, although it is also found in other formations, and particularly in clay-slate. The auriferous quartz is often stained of a rusty brown color, from the presence of peroxide of iron, and in many instances presents a cellular or honeycombed appearance. The points to be most carefully examined are the sands of the rivers and streams, or old water-courses, as well as the particles of disintegrated rock which often accumulate in the eddies of ravines formed on the sides of hills by the action of water during great floods. The sections of rock exposed by this action must also be examined with a view to the discovery of veins of auriferous quartz, from which specimens are broken off and afterwards carefully assayed.

The method of conducting a systematic assay of gold ores and alloys will be fully explained afterwards. It is a somewhat tedious and difficult process, requiring considerable experience and a regular assortment of apparatus. But even in the absence of these, a tolerably correct estimate of the amount of gold present may be readily arrived at by the following simple method.

The fragment of rock, supposing the ore to be quartz, is first pounded very fine and sifted, a portion of the sand or powder thus obtained is washed in a shallow pan, and, as the gold sinks, the lighter portions of the substance are allowed to float off. The greater part of the gold is thus left in the angles of the pan; and by adding more of the powder, and repeating the same process, a further portion is obtained. When the bulk of powder, with which the gold is mixed, is thus reduced to a manageable quantity, mercury is added to the mass, and forms with the gold an amalgam, which is afterwards heated in an iron retort to expel the mercury. In this way the proportion of gold contained in a specimen of rock may be ascertained with considerable exactness. The sands brought down by rivers are examined in much the same manner, but do not require the previous pounding; and a fair estimate of their value may be generally formed without the amalgamating process. Sometimes, indeed, the gold may be present in considerable quantity, although in a state of division so minute as not to be readily perceived by the unassisted eye, and, therefore, in examining the earthy residuum, a small magnifying lens will be found of great use.

It is generally considered that the sand of any river is worth working for the gold it contains, provided it will yield twenty-four grains to the hundredweight; but the sands of the African rivers often yield sixty grains in not more than five pounds weight, which is in the proportion of more than fifty times as much, while the Australian rivers have been known to yield considerably more.

SUBSTANCES OFTEN MISTAKEN FOR GOLD.—Though gold, in its separate and pure state, is readily distinguishable from other metals and minerals, by its color, softness, high specific gravity, and insolubility in the simple acids, yet in the mixed state in which it is generally found it requires an amount of chemical skill to apply these tests, and hence, where glittering particles of other minerals appear, they are often mistaken for gold, even by persons who are not entirely ignorant of its characteristics. The substances which most generally lead to this mistake are iron pyrites, copper pyrites, and yellow mica.

Common iron pyrites, or *bisulphide of iron*, which is more frequently mistaken for gold than any other substance, occurs in small cubical crystals, in veins disseminated in the various slate rocks, and in the coal measures. It is of different shades of brass-yellow, and often in fact contains minute traces of gold, though seldom a sufficient amount of that metal to render its extraction profitable. It may be readily distinguished from gold by the application of the magnet, as well as by the following characters: first, instead of flattening like gold under the hammer, it is extremely brittle, and, therefore, readily broken; second, its weight or specific gravity is only about one-fourth that of gold; and lastly, when heated with nitric acid it is dissolved with evolution of copious red fumes, whilst gold, when so treated, remains unaffected. It was only recently the Editor was consulted by a gentleman who imagined he had discovered a gold mine in Ireland. The sample brought turned out to be a fine specimen of sulphide of iron embedded in quartz.

Copper pyrites, or *yellow copper ore*, the second mineral which is frequently mistaken for gold, is a ferrosulphide of copper, and may be considered as a compound of two equivalents of sulphide of iron, and one equivalent of sulphide of copper. This is the ore from which the largest proportion of the copper of commerce is derived. It occurs in a variety of forms, its primitive crystal being the regular tetrahedron. It is formed in lodes or veins, which usually occur either in granite, grauwacké, or clay-slate, and has a strong metallic lustre, and deep brass-yellow color. It may readily be distinguished from gold by the circumstance, that when heated on a piece of charcoal before the blowpipe it loses this yellow color, and fuses into a dull black globule, which, from the presence of the iron, is magnetic. If mixed with carbonate of soda and a little borax, it yields, when similarly treated, in skilful hands, a button of metallic copper. But an easier method to determine the presence of copper is to pulverize the ore in an iron mortar, or with a heavy hammer, dissolving the powder thus obtained in nitric acid, and evaporating the solution nearly to dryness; water is then added, and afterwards ammonia in excess, when, if copper be present, the liquor assumes a rich purplish color, an unmistakeable sign of the presence of copper.

Another method for determining the presence both of iron and copper, is to take some of the scoria left after submitting it to the blowpipe, and, putting this in a test-glass, to pour over it a few drops of hydrochloric acid, when an effervescing solution will be obtained. A little of this liquid is then transferred to another glass—the one to be treated for iron, the other for copper. Into one of the glasses introduce a few drops of ferro-cyanide of potassium, and liquid ammonia into the other. If iron is present, the liquid in the glass to which the ferro-cyanide has been added will become blue, the iron combining with the ferro-cyanogen, and producing Prussian blue. If copper is present in the same glass, but no iron, the liquid will become of a reddish-brown tint, ferro-cyanide of copper being formed. If iron and copper are present together, the two metallic precipitates will be the result, and a purple tint arises from the mixing of the red and blue colors. The liquid in the glass to which ammonia was added will be changed to a brownish tint if iron is present, and to a fine blue if copper is there.

Mica, the third substance often mistaken for gold, is one of the constituents of gneiss granite and mica slate, and gives to the former its lamellar structure. In 1853 great excitement was produced at the Cape of Good Hope, in consequence of the discovery, near Simon's Bay, of a substance said to contain a large proportion of gold. A quantity of this suspected mineral was sent home for analysis, and was found to possess a glistening, yellow, semi-metallic lustre; but when submitted to the searching powers of the microscope, its metallic brilliancy disappeared, especially when viewed by transmitted light. It had then a darkish-grey color, being in thin semi-transparent plates. It was not acted upon by nitric or nitro-hydrochloric acid; and hence, doubtless, arose the error in taking it to be gold. In reality, it was nothing but mica, highly colored with the oxide of iron, and yielding, on analysis, the following constituents:—

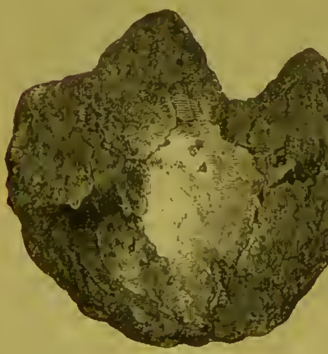
	Centesimally.
Silica,	46
Alumina,	23
Potassa,	14
Oxide of iron,	16
Manganese,	1
	100

The specific gravity of mica never exceeds 3·00; and this circumstance, together with its foliated structure, is quite sufficient to distinguish it from gold, which it somewhat resembles in color; but even in this latter particular, the microscope will dispel the illusion.

CHARACTERS OF NATIVE GOLD.—Gold, as already stated, almost always occurs in the metallic state, generally in small grains or scales known as *gold dust*, sometimes in particles so minute as to be invisible, but occasionally in pieces of considerable weight, termed *nuggets*. It appears doubtful, indeed, whether, when this metal occurs in pyrites, it exists in every instance in minute metallic particles, or whether, in some cases at least, it may not be present in combination with sulphur. The auriferous pyrites, as DUMAS remarks, contain the gold disseminated through their mass in such small quantities, that it is almost always impossible to ascertain, even with the aid of the microscope, in what state the precious metal exists. As a preliminary roasting of this auriferous ore is generally useful, with a view to the subsequent amalgamation, a doubt may be entertained whether it is really present in the metallic state, though this has been generally assumed hitherto. But **Dumas** thinks that the powerful electro-negative tendency of sulphide of gold affords a strong presumption in favor of the hypothesis, that this metal may exist partly, or even entirely, under the form of a double sulphide, in iron and copper pyrites, *et cetera.* **Brogniart** observes, that it is chiefly in its association with these sulphides, as also with galena or sulphide of lead, blende or sulphide of zinc, and mispickel or arsenical pyrites—a sulphide of arsenic and iron—that the gold becomes invisible to the eye, a circumstance which is justly regarded as strongly confirming the opinion expressed by **Dumas**. The other minerals with which it is found associated are grey cobalt, lithoidal manganese, native tellurium, malachite, sulphide of silver, red silver, and sulphide of antimony.

When the gold is found in the form of nuggets, these generally communicate the impression of their having been melted; and in many newspaper accounts, and letters received from the diggings, the gold is described as having been evidently in a state of fusion, and as resembling drops of melted metal poured into sand, the indentations being visible even upon the smallest particles of the gold when microscopically examined. It is certain that such indentations may be observed in most specimens, as indicated in Fig. 206, which exhibits a microscopic view of a fragment of Australian gold magnified seven hundred times.

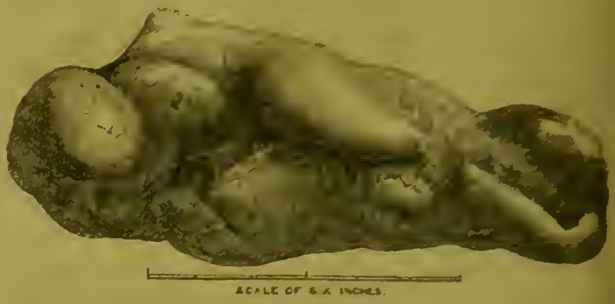
Fig. 206.



Mr. J. B. **Jukes**, however, who may be regarded as a competent authority, conceives that this is probably a mistake, and that the idea may have originated from the gold having been deposited in small holes, crevices, and interstices of the quartz rock, and subsequently rolled, so that it assumes such forms as melted lead is seen to do. It does, certainly, appear remarkable that the particles of gold should retain indentations received in a state of fusion, after being tossed about, probably for a long period, among water and gravel.

Fig. 206 has been given as the greatly magnified representation of a very small grain. Fig. 207, on the contrary, is a much reduced delineation of a lump of almost pure gold, weighing 27 lbs. 6 oz. 15 dwts, which was found in the diggings, at Forest Creek, Mount Alexander, in the Colony of Victoria. Among other pieces brought home with it in the same vessel, were several nuggets weighing upwards of a pound each, and one of 1 lb. 8 oz. 6 dwts. These smaller lumps, however, contained quartz, whilst the larger one appeared a massive lump of nearly pure gold, of a very fine color. It measured eleven inches in length by five in breadth, at the widest part. This was supposed to be the largest nugget which had been found in Australia up to the time of its discovery, but one or two others considerably larger have been since obtained.

Fig. 207.



Gold is also occasionally, though rarely, found in a crystallized state; and when met with, the crystals should be carefully preserved as cabinet specimens, for which purpose their value is much greater than that which they are intrinsically worth for the gold they contain. The most common forms are the cube and octahedron, with their various modifications. The faces are generally dull, and in most instances the edges are slightly rounded. Some years ago, several interesting specimens of crystallized gold, from California, were described in *Silliman's American Journal*, by Mr. **Francis Alger** of Boston. The collections in which the specimens were found were brought from California by Mr. G. E. **Tyler** of Boston, and Mr. H. B. **Platt** of New York. The crystals were distinctly octahedral, simple and modified, the surfaces being but slightly disfigured by attrition, or the effects of transported action—a very unusual circumstance, as gold is generally found in comparatively minute grains at a distance from the rocky matrix in which it is supposed by some to have been primarily embedded. Mr. **Alger** states in his paper, which was read before the Boston Society of Natural History, that he had never before seen what was unquestionably a genuine crystal from California. He adds that an irregular crystalline plane could only occasionally be traced out in former specimens; but among those exhibited were examples of crystallization as perfect, among the small ones especially, as are to be seen in magnetic iron ore or in spinelle.

Of the larger specimens in these collections, the most striking examples were three octahedrons of the sizes exhibited in Figs. 208, 209, 210. Each of these crystals was found in an isolated state. The smallest one—Fig. 208—was the most perfect, and was entirely free from any adhering portion of the matrix. This unusually perfect crystal exhibits, as partly shown in the Figure, four pretty regular faces in the lower half, and three of its six solid angles are perfectly formed to a point. Two of its faces are sunk or depressed; and in one of them, the cavity thus formed, is very deep and regular, like an interior triangle; the depression extending not quite to the edges, but so as to leave all round a narrow ridge or border, the interior sides of which are parallel with the edges of the crystal. Mr. ALGER inferred that this depression, which is shown by a darker shade in the wood-cut, had been formed when the crystal was in a liquid state, and that, soon after the outside had congealed or solidified, the inner portion, or a part of it, had run out, leaving the surrounding consolidated edge in a perfect form. He remarks that he has seen something similar to this formed among artificial crystals, as, for instance, metallic lead—which takes the form of an octahedron—and lead ore partially desulphurized, when the metal was allowed to flow off slowly, just as the outer crust had formed over the surface of the crystals. Indeed, this parallel case is of not unfrequent occurrence in the crystallization of the ductile metals.

Fig. 208.

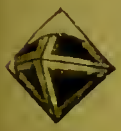


Fig. 209.

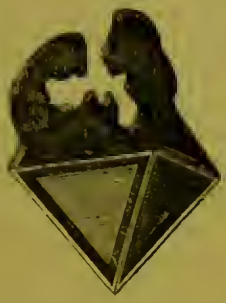
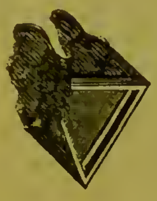


Fig. 210.



In the largest—Fig. 209—of the three crystals of which the preceding sketches are given, it will be observed that only one-half of the octahedron is formed, its base blending with the rough gold, or showing only the commencement of the planes of the upper pyramid. Three of the planes are quite smooth, except along their edges, which are permanently marked by the same projecting border or edge described on the smaller crystal. The depression, however, is not so great as in the latter. Mr. ALGER remarked that this peculiarity was confined to the unmodified crystals.

In some there was a double series of these ridges, the inner one appearing to exhibit the commencement of another crystalline face within the cavity of the larger one. This phenomenon was strikingly shown in a crystal represented of the natural size in Fig. 210.

The two larger crystals—Figs. 209 and 210—were obtained from the collection of Mr. PLATT, who resided a couple of years at San Francisco, and being in a situation which brought him into constant intercourse with persons returning from the mines, purchased, at no small expense, the most interesting specimens he could find. His collection was described by Mr. ALGER as of singular beauty and value, comprising a great variety of ramified, arborescent, dendritic, and other imitative forms, all of them, sometimes, fantastically joined together in the same specimen. In obtaining his valuable collection, he had examined gold to the amount of more than four millions of dollars. The remarkable size of the two larger crystals thus described, and the fact that some of the others contained portions of oxide of iron, induced a suspicion that the greater part of them were pseudomorphs of sulphide of iron; but Mr. ALGER believed that they were formed under the ordinary circumstances of crystallization, either in an open space, or while surrounded by a matrix, in such a fluid state as to allow them full freedom to take their natural form. His reasoning on the subject, if not perfectly conclusive, leads to a strong presumption in favor of the octahedron as the primary form of gold; and if this were more generally known, much disappointment and trouble might be saved in cases where sulphide of iron and other crystalline metallic forms are mistaken for the precious ore.

In Mr. TYLER'S collection, Mr. ALGER found several rare modifications, some of them resembling those which come in their most perfect forms from Brazil. Fig. 211 exhibits in three positions, *a*, *b*, *c*, a compound form produced by the union of two opposite segments of an emarginated octahedron. Fig. 212 is a modification of the same form, though apparently consisting of irregular six-sided tables, with truncated edges. Some of the unmodified macles, as shown in different positions, in Fig. 211, were stated by Mr. ALGER to be very distinctly formed, the edges between *e e*, uniting the two segments of the octahedron, being well defined. This is very strikingly shown in Fig. 213, in which the crystals are exhibited as magnified to twice their natural size. Fig. 214 shows the opposite side of the same specimen, connected with two other crystals, one a very beautiful and smooth-planed octahedron with emarginated edges.

Fig. 211.

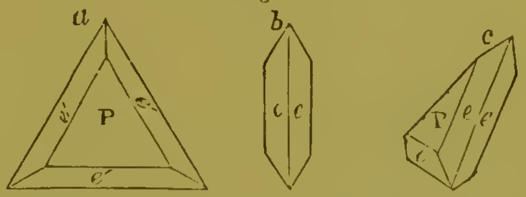


Fig. 212.

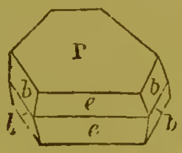


Fig. 213.

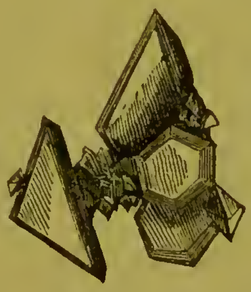


Fig. 214.

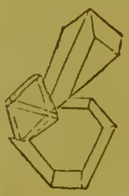
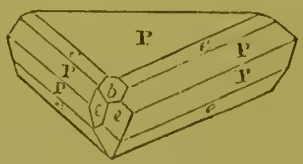


Fig. 215 exhibits a macle of gold which came from Malto-Grosso in Brazil, and is in the collection of the School of Mines, Paris. It is similar to that represented in Fig. 211, from which it only differs in exhibiting more of the planes of the octahedron and dodecahedron. This figure is copied from the volume of crystallographic illustrations accompanying M. DUFRÉNOY'S treatise; but besides conforming his lettering to the notation of PHILLIPS, those are made primary planes which are given by DUFRÉNOY only as secondaries of the cube.

Fig. 215.



In all these the octahedral form is manifest, which may therefore be assumed to be the form natural to gold when its particles crystallize in cooling; but as nearly all of these crystals show the effects of abraded action, it is often difficult to distinguish planes confined within such narrow limits, and which are too small or too rough to admit of accurate admeasurement. Indeed the faces of the crystals are in most instances slightly rounded, even in specimens obtained directly from veins, and which, consequently, cannot have been exposed to attrition.

Composition of Native Gold.—Native gold is never quite pure, being almost invariably alloyed with silver, and containing frequently small proportions of copper and iron. In Siberia it is often associated with platinum, and in the Gongo Soco mines in Brazil, an alloy of gold and palladium of a pale yellow color is sometimes found. In Columbia a somewhat similar mixture is procured, in which the palladium is replaced by another rare metal called rhodium. In Hungary it is met with in combination with tellurium and other elements. The specific gravity of native gold varies from 13·3 to 18·5.

The proportion of silver, the principal ingredient which is found in combination with gold, varies from one to fifty per cent.; and not only differs greatly in specimens of native gold obtained from diverse regions, but even to a certain extent in specimens from the same auriferous district. In general, however, the composition of the gold of the same district is remarkably constant; so much so, that the knowledge of the locality whence it is derived is often sufficient to enable the experienced assayist to guess pretty nearly the quantity of pure gold which the compound contains. The subjoined table presents the composition of native gold from various parts of the world:—

Locality.	Authority.	Gold.	Silver.	Copper.	Iron.
	SIBERIA AND URAL.				
Schabrowski,	Rose,	98·96	0·16	0·35	—
Boruschka,	Rose,	94·41	5·23	0·36	
Katherinenburg,	Rose,	92·80	7·02	0·06	0·08
Gozuschka,	Rose,	83·85	16·15	—	—
Ural,	Awdejew,	70·86	28·30	0·84	
	AFRICA.				
Anamaboc,	T. H. Henry,	98·06	1·39	0·15	
Anamaboc,	T. H. Henry,	88·25	11·17	0·10	0·36
	AMERICA.				
North of Brazil,	Rivot	91·0	8·7	0·3	Palladium.
Gongo Soco,	T. H. Henry,	83·36	6·44	0·50	3·58
Ojas Anehas,	Boussingault,	84·5	15·5	—	—
Santa Rosa De Osos,	Boussingault,	82·4	15·5	—	—
Marmato,	Boussingault,	73.45	26·48	—	—
Titiribi, Columbia,	Rose,	76·41	23·12	0·03	—
California,	T. H. Henry,	90·12	9·01	0·87	Iron.
California,	T. H. Henry,	86·57	12·33	0·29	0·24
Canada,	T. H. Henry,	90·38	9·53	—	—
	AUSTRALIA.				
Bathurst,	T. H. Henry,	95·68	3·92	—	0·16
	EUROPE.				
Transylvania,	Rose,	60·49	38·74	0·77	
Wicklow,	Mallet,	92.32	6·17	—	0·78

From this table it will be seen that the gold both of California and Australia contains silver, but that the specimen from the latter was remarkably pure; and such, indeed, is the general character of Australian gold. Neither platinum nor palladium, nor any trace of the metals of that class, is found in the newly discovered gold regions. There is, however, a trace of iron in the Australian specimen, and a small proportion of both copper and iron in those from California.

Preparation of Pure Gold.—Like native gold, that which is used in the currency, as well as in the manufacture of jewellery, is never absolutely pure, being always alloyed with some other metal, such as copper or silver, to give it the requisite hardness. The proportions of the metals which enter into these alloys will be afterwards stated. The methods adopted, also, for obtaining pure gold on the large scale, or, in other words, the metallurgical treatment of gold ores, with a view to the extraction of the precious metal in a state of purity, will be fully explained. In the meantime, it may be desirable, before proceeding further, to show how a small portion of pure gold may be prepared in the laboratory.

For this purpose, a piece of native gold, a small quantity of gold dust, or a few coins or fragments of old jewellery are dissolved in nitro-hydrochloric acid —the *aqua regia* of the alchemists—consisting of four parts of hydrochloric with one of nitric acid. This will give a solution of terchloride of gold, mixed with chloride of silver, if any of that metal be present. The solution thus obtained is evaporated with an excess of hydrochloric acid for the purpose of destroying the excess of nitric acid. The residue is then treated with hot water, by which it is dissolved, with the exception of the chloride of silver, from which the solution is decanted or separated by filtration.

An excess of protosulphate of iron in solution is then added to the auriferous solution in the proportion of four or five parts of the crystallized protosulphate—green vitriol—to one of gold; and the mixture is put in a warm place, and allowed to stand for several hours. In the reaction which occurs, the chlorine that was combined with the gold unites with a portion of the iron of the protosulphate, part of which is thereby converted into sesquisulphate, while sesquichloride of iron is at the same time formed, and metallic gold is precipitated. This reaction is represented in the annexed equation:—

$$6\,(Fe\,O,\,SO_3) + Au\,Cl_3 = 2\,(Fe_2\,O_3,\,3\,SO_3) + Fe_2\,Cl_3 + Au.$$

To precipitate the gold from an acid solution of its chloride, Levol prefers to the protosulphate of iron an acid solution of terchloride of antimony, in which case the following equation exhibits the reaction that takes place:—

$$3\,Sb\,Cl_3 + 2\,Au\,Cl_3 = 3\,Sb\,Cl_5 + 2\,Au.$$

In this case, if chloride of silver be present, it is retained by the hydrochloric solution.

The precipitated gold is in the form of a finely-divided powder, which, when suspended in water, is brown by reflected and purple when viewed by transmitted light; but under the burnisher it readily assumes the metallic lustre and characteristic color of malleable gold. It also admits of being aggregated and welded together by percussion; and if heated to whiteness, and in that state struck repeatedly with a heavy hammer, its particles become united into a solid mass, without having been raised to the point of fusion.

To obtain the gold in a perfectly pure state, however, the precipitated powder is boiled with hydrochloric acid of specific gravity 1·1, which is then decanted, and the residue is boiled twice with fresh acid. The gold is *not* washed between these successive treatments with acid, which remove the last traces of iron, and nearly all the chloride of silver.

Lastly, the gold is well washed, dried, and mixed with its own weight of bisulphate of potassa, or a small quantity of borax and nitre, and fused in a Hessian crucible exposed to a very strong heat. By this operation, the last portions of chloride of silver are removed, and a button of perfectly pure gold is obtained.

Properties of Pure Gold.—Pure gold is of a rich reddish-yellow color, and high metallic lustre; in the pulverulent state it is brown and dull, but acquires, as has been stated, the metallic lustre by pressure. The specific gravity of fused gold is 19·2; of hammered gold, from 19·3 to 19·4. In this respect, therefore, it stands only second to platinum, of which the specific gravity is about 21·5. Finely-divided gold, precipitated by sulphate of iron, was found to vary in density from 19·55 to 20·72; and when precipitated by oxalic acid, its density was 19·49. Its equivalent is 197. In a pure state it is softer than silver, and nearly as soft as lead; but its tenacity is so great that it may be drawn out into very fine wire; and such is its malleability that it may be hammered out into leaves only one three hundred and seventy thousandth of an inch in thickness. A single grain may be extended over 56·75 square inches of surface, or drawn out into a wire five hundred feet long. Réamur, by rolling out a fine gilt silver wire, reduced the coating of gold to the twelve-millionth of an inch in thickness, and the surface appeared to be perfect when viewed under the microscope.

Gold does not combine directly with oxygen, and, therefore, suffers no change by exposure to air and moisture at any temperature—not even by being kept in a state of fusion in open vessels. It is not attacked by the mineral or any of the simple acids, except selenic, and this by the aid of heat. The alkalies do not affect it, and hence a crucible of gold is a valuable instrument in the analysis of minerals which require fusion with the caustic alkalies. It is not acted on by sulphur, and, consequently, sulphide of hydrogen is not decomposed by it, as in the case of silver. Iodine has only a weak action upon it, but bromine and chlorine attack it easily at ordinary temperatures; and it is dissolved by any substance which liberates chlorine. It is therefore dissolved by hydrochloric acid, if binoxide of manganese, chromic acid, *et cetera*, be added thereto. Its usual solvent is that already stated—a mixture of one part of nitric acid, and four parts of hydrochloric acid. *The proper solvent of gold is nascent chlorine*, which is eliminated by the mutual action of the mixed acids.

Gold is one of the most perfect conductors both of heat and of electricity. It fuses at a bright red or a white heat, the temperature of which has been estimated at 2016° Fahr. It is therefore less fusible than silver or copper, the former fusing at 1873°, and the latter at 1996°. In fusion it exhibits a bluish-green color. It is not sensibly volatile in the strongest heat of a blast furnace; but in the focus of a large convex lens, in the intense heat of the oxyhydrogen jet, or under the influence of a powerful electric discharge, a gold wire is dispersed in vapor; and if, in the latter case, the wire be placed just above the surface of a sheet of paper, the course of the discharge is marked by a broad, dark, purple stain, produced by the finely-divided gold. If, instead of the sheet of white paper, a plate of polished silver be employed, it is traversed by a brightly-gilded line, which is firmly attached to its surface. When a globule of gold is placed between the terminal charcoal points of a powerful voltaic battery, it enters almost immediately into fusion, and gives off abundant metallic fumes.

Gold contracts on cooling, and cannot be advantageously employed for castings, as it shrinks greatly at the moment of solidifying. Graham states that it cannot be obtained in crystals by cooling; but according to other authorities, when large quantities of gold have been fused, and are then allowed to cool slowly, cubes more or less modified on their edges and angles are frequently the result. It has been shown that native gold affords numerous well-defined crystals belonging to the cubic system, and that of these the greater number, if not all, is affected by the faces of the regular octahedron.

Chemical Examination of Gold Ores.—A rude method of ascertaining the presence of gold in crushed quartz, or earthy ore, by washing with the hand-basin, has been described; but gold is often present in the matrix in grains or particles so minute that it cannot be detected by the eye, and sometimes it is quite disguised by admixture with other metals or minerals. Many cases occur, however, in which it is of great importance to ascertain the presence of gold, not only as a first step in the examination of suspected auriferous ores, but likewise in the assaying of alloys of gold with different metals. In commencing mining operations, the fact of the *presence of gold* in the ore, in any appreciable quantity, is the first point to be determined; and if this be decided in the affirmative, the next point is to determine the *proportion or quantity of gold* contained. The first process is termed *testing for gold*, or the *qualitative examination* of a suspected mineral; the second is the *quantitative examination*, or *assaying* process.

Sulphate of iron, protochloride of tin, and oxalic acid are the tests or reagents pre-eminently employed in seeking to determine the presence of gold.

Before any of these tests can be applied, the substance supposed to contain the gold must be brought into a state of solution; and this can only be done by means of the mixture of nitric and hydrochloric acids already mentioned. If the substance consist of earthy or quartzose matter, this must be reduced to powder by trituration in a mortar before it is subjected to the action of the solvent; but if the matter under examination be simply a metallic alloy, it can be dissolved without any previous preparation. An excess of acid should be avoided, and for this purpose some carbonate of soda should be added. When the solution is effected, the liquid should be evaporated to about one-eighth of its original bulk, and then diluted with three or four ounces of water. The action of the reagents is as follows:—

1. *Sulphate of Iron or Green Vitriol.*—If a few crystals of this salt be dissolved in distilled water, and dropped into the suspected solution, the result is the precipitation of the gold, if any be present, in the form of a dark-brown powder, which is metallic gold in a very fine state of division, as already described in connection with the laboratory process for preparing pure gold. If the solution has been mixed with a considerable quantity of water, the liquid, on the addition of the green vitriol, is colored brown by reflected, and blue or a dingy green, by transmitted light; and this is obvious even when forty thousand parts of the menstruum are present to one part of gold. If the liquid amount to eighty thousand parts, it is colored sky-blue; with one hundred and sixty thousand parts, it becomes violet; with three hundred and twenty thousand parts of liquid, the violet tint is still very obvious; but with six hundred and forty thousand parts, it is with difficulty perceived.

The deposit formed when the sulphate of iron is added may be corroboratively proved to be gold, by its being insoluble in nitric acid, but readily soluble in aqua regia.

2. *Protochloride of Tin.*—If to another portion of the nitro-hydrochloric solution be added a small quantity of a solution of protochloride of tin—commonly known as *salts of tin*—there will be immediately produced, if any gold is present, a dark brownish-purple precipitate, known as *purple of Cassius.* This substance is used in enamel and porcelain painting, and also for tinging glass of a fine red color, in connection with which applications it will be noticed afterwards. Its color, though not a brilliant purple, but rather a reddish-brown, is characteristic, and after being once seen is not likely to be mistaken. Its appearance, when the chloride of tin is added to the liquid, affords an infallible proof of the presence of gold, for a very minute portion of that metal gives a manifest reaction when this test is employed.

When the first test—sulphate of iron—has been applied, and its evidence corroborated by the solution of the precipitated gold powder in aqua regia, the protochloride of tin may be employed to produce the purple of Cassius in this solution also.

3. *Oxalic Acid.*—This substance, either in crystals or dissolved in water, causes, when added to the nitro-hydrochloric solution, the precipitation of any gold that may be present, in the form of a brown or greenish-black powder, in the same manner as the sulphate of iron; but the precipitation does not occur so rapidly. Indeed, it requires not less than forty-eight hours for the whole of the gold to be thrown down by the oxalic acid, unless heat is applied, by which the process is accelerated. The precipitate is pulverulent gold, and may be tested, as in the first case, by its insolubility in nitric acid, while readily dissolving in aqua regia. A crystal of oxalic acid, wetted with a solution of gold, becomes soon covered with a thin film of the metal, having its distinctive color and lustre.

These are the tests most easily applied by persons unaccustomed to chemical manipulation. At the same time, it may be useful to know the reactions of gold with various other substances, the most important of which, including the three already mentioned, are summarily tabulated as follows by Dr. Lyon Playfair, in a lecture delivered by that chemist at the Museum of Practical Geology:—

TESTS FOR GOLD.

Tests or reagents.	Results.
Sulphate of iron,....	In acid solution, brown precipitate; if very dilute solution, only a blue coloring.
Protochloride of tin,........	In dilute solution, a purple-red coloring; when strong, almost brown precipitate.
Metallic zinc,..............	Precipitates metallic gold as a voluminous brown precipitate.
Potassa in excess,..........	No precipitate; after some time a green coloring and slight precipitate.
Ammonia, ...	Yellow precipitate—fulminating gold.
Carbonate of soda, or carbonate of potassa, ...	No precipitate in cold solutions, but when heated, voluminous precipitate like oxide of iron.
Bicarbonates of soda or potassa,....................	No precipitate.
Carbonate of ammonia,......	Behaves like ammonia, carbonic acid being evolved.
Oxalic acid, ...	Dark, greenish-black precipitate, more quickly produced by heat.
Tartaric acid and soda,......	Dark precipitate when boiled.
Sulphide of ammonium and Sulphide of hydrogen,.....	Dark brown or black precipitate.

These reactions are so characteristic that it is impossible to mistake gold for any other metal. At the same time, it may be stated that the protochloride of tin is the most infallible test, and is indeed quite conclusive. It has the advantage of being more delicate than the others—that is to say, it will indicate the presence of a smaller quantity of gold than any other reagent, not excepting the protosulphate of iron or the oxalic acid.

TESTS FOR METALS USUALLY ASSOCIATED WITH GOLD.—In examining an ore or alloy supposed to contain gold, it is often an object of great importance to determine the nature of the metals with which the gold is associated. These may be of high value on their own account, and, according to the quantities in which they are present, may greatly affect the value of the ore or mineral in question. To enter fully into this subject in connection with the rarer metals that are found associated with gold, would be of little practical use. The Editor will therefore confine his attention to the means of detecting and distinguishing those of most common occurrence—copper, silver, and platinum.

1. *Copper.*—It has been shown that copper is almost always associated with gold even in quartz, and that copper pyrites is one of those substances frequently mistaken for gold. When dissolved in acids, however, it gives characteristic actions, which render its presence easily distinguishable. One of the readiest tests is to introduce into the solution a piece of clean iron, when, if copper be present, it will be deposited on the iron in the metallic state. This experiment, remarks Dr. LYON PLAYFAIR, apparently showing the conversion of iron into copper, deceived the alchemists in their researches, and gave much support to the idea that one metal may be transmuted into another. The action depends, however, upon a simple exchange, the iron going into the solution in proportion as the copper goes out. Again, when ammonia is added in excess to a solution in which copper exists, it communicates to the liquid a rich deep blue color. Ferrocyanide of potassium produces, with copper, a brownish-red precipitate, even when the metal is present in very small quantity. Carbonate of soda precipitates copper from its hot solutions in the form of an apple-green compound, which is a carbonate of copper, known, when artificially formed, as *verditer*, and when it occurs native, as *malachite*. Copper ore in the latter form exists abundantly in Australia—not, indeed, mixed with the gold, but constituting valuable mines, from which the ore is sent over to this country, with great profit, to be smelted in South Wales.

2. *Silver.*—It has been shown that gold appears to be invariably alloyed with this metal, sometimes to a very large amount. In its separate state it is readily distinguished, not only by its white color, but also by its specific gravity, which is only 10·4, or about one-half that of gold. It may be useful to state, that when in a very fine state of division, it is of a dark-grey color. It may be easily recognized by its chemical behavior to reagents, in which respect it differs from gold by its solubility in nitric acid at all temperatures, and in boiling or heated sulphuric acid. On the contrary, with hydrochloric acid, it forms a white curdy precipitate, which is the chloride of silver. If the nitric acid employed to dissolve it contain the least hydrochloric acid, the solution will become turbid by the formation of the chloride. Hence, when a mineral containing gold and silver is submitted to the action of aqua regia —nitro-hydrochloric acid—the appearance of this white precipitate will immediately indicate the presence of the latter metal. The chloride of silver is soluble in ammonia, and may thus be distinguished from many other white precipitates; or it may be further tested by putting the precipitate into a crucible with carbonate of soda, and exposing the mixture to a strong red heat, when a button of pure silver will be obtained. By careful manipulation the amount of silver present may be accurately determined in this manner. If the mineral containing the silver be dissolved in oil of vitriol, it is readily detected by inserting a few fragments of copper, which causes the precipitation of the silver in a pulverulent state.

From the fact that silver, in greater or less proportion, is uniformly associated with gold in the native state, it may be useful to compare the following reactions with those given in the preceding page for the metal of higher value:—

TESTS FOR SILVER.

Tests or Reagents.	Results.
Potassa,	Brown precipitate, becomes black on boiling.
Ammonia,	Brown precipitate, soluble in excess of ammonia.
Carbonate of soda or potassa,	White precipitate, soluble in ammonia.
Carbonate of ammonia,	White precipitate, soluble in excess of reagent.
Phosphate of soda,	Yellow precipitate, soluble in ammonia.
Oxalic acid,	In neutral solutions, white precipitate.
Sulphide of hydrogen and sulphide of ammonium,	Black precipitate.
Hydrochloric acid,	White curdy precipitate, soluble in ammonia.
Zinc or copper,	Precipitates white metallic silver.
Sulphate of iron,	In neutral solutions, white metallic silver.

3. *Platinum.*—This is another metal frequently associated with gold; and as it is one of the noble metals, and ranks in price between silver and gold, an ore which contains it in any considerable quantity is of great value. The specific gravity of platinum is about 21·5, and is, therefore, greater than that of gold. In short, platinum is the heaviest of all known substances. It is of a light steel-grey color, less ductile than gold or silver, but more tenacious, and will support greater weights on equal thicknesses of wire than any metal except iron or copper. It is distinguished from gold not only by its color, but also by its extreme difficulty of fusion; it does not melt by itself in the highest heat of a furnace, but softens sufficiently to admit of forging and welding, and in the arc of flame of the voltaic current, or before the oxyhydrogen blowpipe, it admits of being fused even in considerable masses. On the other hand, it resembles gold not only in its high specific gravity, as already stated, but also in the fact that it resists the action of all the simple acids, and is soluble only in aqua regia. This circumstance, together with its great infusibility, renders it importantly useful in many of the arts, and indispensable for various purposes in the chemical laboratory. It is the metal universally employed for apparatus which requires to be exposed to high temperature and powerful chemical agencies, without undergoing any change. It is, therefore, very desirable, as Dr. LYON PLAYFAIR has remarked, that those who go to the gold regions should look well for this precious metal, as it is likely to escape

the notice of the common observer from its less glittering appearance.

There are, however, certain chemical reactions by which platinum may be readily distinguished and separated from the gold in solution. Sulphate of iron and oxalic acid, which precipitate gold, do not precipitate platinum. When the latter is dissolved in aqua regia, and the acid neutralized by carbonate of soda, it is deposited as a black powder, if the mixture be boiled with tartaric acid and soda—the ingredients of a Seidlitz powder. Further, the addition of chloride of ammonium and alcohol to a strong solution of platinum, causes the deposition of a yellow crystalline precipitate, which is characteristic of this metal. These and other reactions may be summarily stated as follows:—

TESTS FOR PLATINUM.

Tests or Reagents.	Results.
Chloride of potassium or chloride of ammonium, ...	Yellow crystalline precipitate produced readily by the addition of alcohol.
Potassa or ammonia,........	With chloride of platinum acts like the chlorides of potassium and ammonium.
Carbonates of potassa and ammonia, ...	In chloride solution yellow precipitate.
Carbonate of soda,..........	No precipitate.
Sulphate of iron,...........	No precipitate.
Oxalic acid,...............	No precipitate.
Protochloride of tin,........	Dark-brown red coloring, no precipitate.
Sulphide of hydrogen and other sulphides,..........	Dark-brown nearly black precipitate.
Tartaric acid and soda,......	On boiling, metallic platinum falls as a black powder.
Zinc, ...	Slowly precipitates metallic platinum as black powder.

Application of the Reagents.—Having thus described the properties and characteristic reactions of the different metals which it is desirable to look for as being frequently associated with gold, let it now be assumed that the substance to be examined is a piece of auriferous quartz. This must be first reduced to powder, and then boiled for some time in an earthenware or glass dish with aqua regia. The solution is then diluted with water, passed through a filter, and allowed to cool. If any silver be present, it will remain in the filter as a white precipitate, mixed with the quartz.

To the liquid which has passed through the filter, a solution of carbonate of soda is now added, until no more effervescence takes place. This will precipitate all the other metals which may be present except gold and platinum. These will remain in solution.

The liquid is again filtered, and a solution of oxalic acid is added until it ceases to produce effervescence, and has a sour taste; then boil; if there be any gold present, it will be precipitated as a black powder. The platinum, if any be present, will still remain in solution.

Decant or filter the liquid from the gold precipitate, and add to the former protochloride of tin, when a reddish-brown coloring will appear if platinum be present. Or, by boiling with tartaric acid and soda, the platinum will be thrown down as a black precipitate.

It has been stated that if any silver be present, it will be found on the first filter, mixed with the quartz. Wash this with ammonia, which, if copper be present, will produce a deep blue tinge. To the solution which comes through, add hydrochloric acid until the smell disappears, and the silver will be thrown down as a white curdy precipitate.

It is evident that other methods and reagents may be adopted. For example, the original solution in aqua regia may be concentrated by evaporation, until it is very much reduced in quantity; then add about three-fourths of its bulk of spirit of wine, and, lastly, a saturated solution of chloride of ammonium. By these reagents the platinum will be thrown down as a yellow crystalline precipitate, while the solution filtered from this, and treated with sulphate of iron or boiled with oxalic acid, deposits gold.

By carefully weighing the gold obtained, the amount present in a given quantity of the ore or alloy may be exactly determined; but full details of the different methods of conducting the quantitative examination, including the assaying of gold ores and alloys by the dry process, will, to avoid repetition, be postponed to the close of the article.

GOLD-DIGGING TOOLS.—When the fact has been ascertained that a rock or soil really contains gold, and this in sufficient quantity to repay the labor of extracting it, the first operation is that of digging the soil or reducing the rock to fragments, with a view to its preparation for the subsequent processes. For the former of these purposes, the spade, the hammer, the pick-axe, and other common tools are employed; but for the special use of the gold-digger, who cannot conveniently carry a complete assortment of these, an ingenious combination of five tools, adapted for a single handle, has been contrived by Mr. T. LEE of Birmingham. Four of these are represented in the three annexed cuts.

Fig. 216. Fig. 218. Fig. 217.

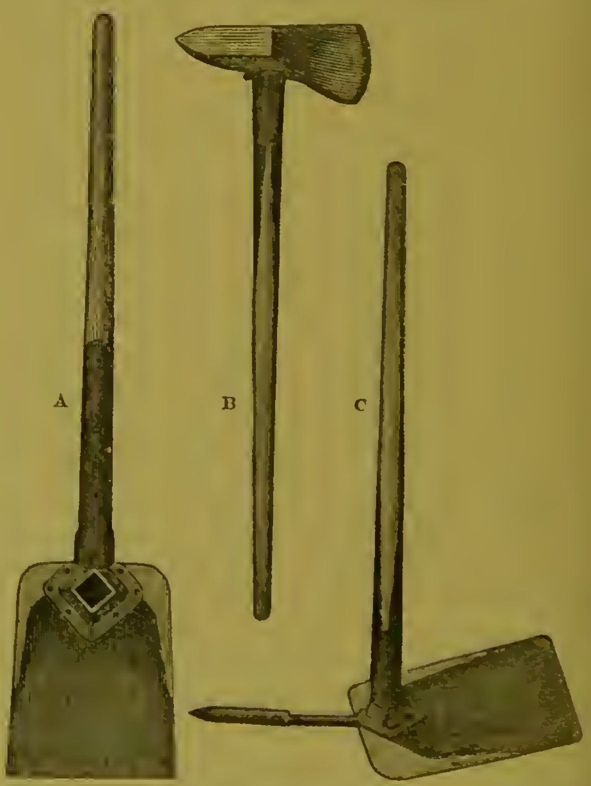
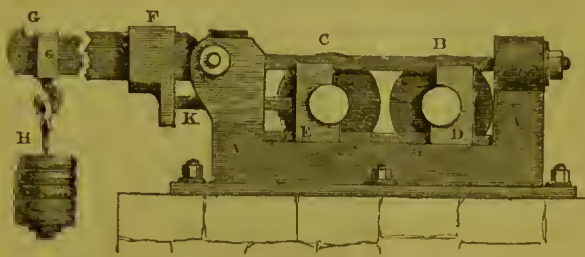


Fig. 216 is a steel shovel, with loose handle fitted to it, to suit all the varieties. Fig. 217 is the same shovel, altered for use as a pick and scraper; this alteration is effected by withdrawing the prong of the pick from a hollow socket made in the handle for its reception, and fitting the end of the handle into the eye shown in the shovel. Fig. 218 is the same handle fitted with an axe, formed with a pointed hammer, for granite-breaking. A fourth arrangement admits of forming the fifth tool, a powerful crow-bar, by fitting a short additional bar to the universal handle. Armed with this combination-tool, as the inventor terms it, the gold-digger is independent of the extensive array of ordinary implements; since, with the form of the apparatus represented in Fig. 217 on his shoulder, and the axe-head and short point of the crow-bar in his hand, he may journey freely to the scene of his operations; and when he commences work he is ably assisted by the peculiar fitness of the several combinations for the purposes of excavation. The incessant hard work of a pick rapidly wears away its point; but the combination-tool makes provision for one or more extra points to fit on the end of the pick. These are of small weight, and may be carried in the pocket. The pick, working in conjunction with the steel plate of the shovel, which is in the position of a scraper, to remove the loosened earth, effects a saving of time, while the quick change from one tool to another causes but little delay, in proportion to the convenience secured by the great portability of the arrangement.

MECHANICAL PREPARATION OF GOLD ORES.—Before subjecting the ore, or the auriferous gangue, to the chemical or metallurgical processes by which the gold is extracted, it has certain mechanical operations to undergo, the number and nature of which will be determined by the character of the ore itself, and its state of aggregation. The metal is rarely found in the shape of large nuggets, requiring only to be cast into ingots. It is generally either in the shape of dust, or spangles, or small grains intimately mixed with the quartz rock or the alluvial soil; and though far the greatest amount of gold is obtained by the direct washing of alluvial deposits, yet, as a considerable and perhaps increasing proportion is extracted from the solid rock, it seems to be the natural order to begin with those operations by which the rock is artificially reduced to the state of an auriferous sand or pulverized ore. These operations are *crushing*, *stamping*, and *grinding*, and are usually conducted by regularly-established mining companies, while individual diggers confine themselves to the washing of soils on which the same operations have already been performed by nature.

Crushing.—To reduce the fragments of ore, as obtained from the mine, to the proper size for their subsequent mechanical concentration, it is obvious that various arrangements may be employed, although in every instance the principles involved must be very nearly the same. For this purpose, the machine represented in Fig. 219 is frequently used, and consists of two large cylinders or crushing rollers, B, C, of cast-iron, moving in contrary directions in a strong iron framework, A A, secured to a solid wooden frame by means of screw-bolts. The bearings, D, E, of the rollers are so arranged as to slide in grooves, and consequently admit of the cylinders being either brought nearer to each other or separated to a greater distance. To admit of the passage of large pieces of stone too hard to be broken, a certain elasticity is given to the machine by means of the lever, F G, which, by a sliding bar, and the shoulder, K, constantly tends to keep the surfaces of the two grinding cylinders in contact, being loaded at its extremity with a heavy weight, H, which is adjusted to the hardness of the mineral to be broken.

Fig. 219.

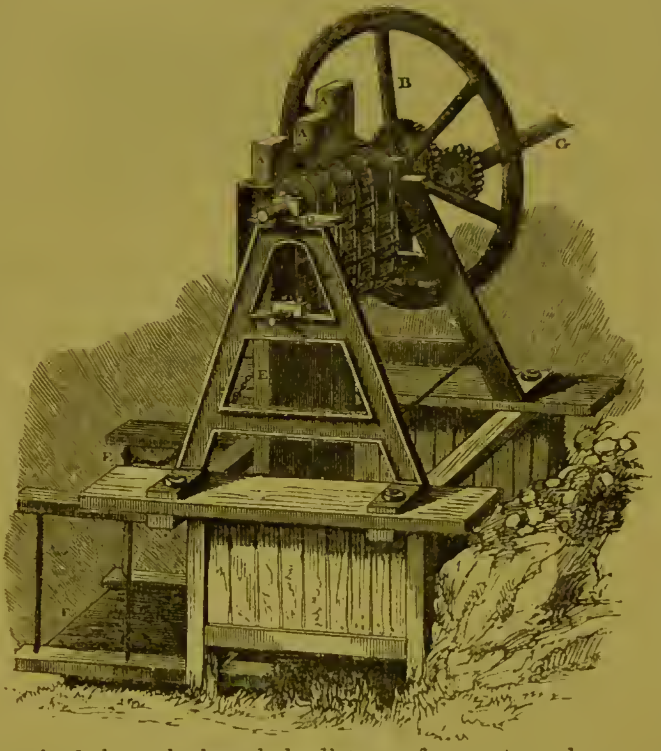


After passing between the rollers, the crushed ores fall into the upper end of an inclined cylinder of coarse wire gauze, similar in construction and operation to that which is described in Vol. I., p. 169, in connection with the alum manufacture, and is there represented on the right hand side of Fig. 97. This cylinder receives an oscillatory motion from the same steam or water power which impels the rollers, and divides the pulverized ore into two classes; that which passes through the meshes of the gauze falls on the floor of the building, whilst those grains which are too large to pass through the sieve are carried out at its lower end, and fall into the buckets of an endless chain, by which this portion is again brought to the level of the hopper over the rollers for the purpose of being subjected to another crushing.

Stamping.—When the ore is required to be reduced to a finer state of division than can be readily effected by means of the crushing rollers, it is usually subjected to the pounding action of large wooden pestles, armed with iron heads, and moved either by steam or water power. The vertical wooden beams of which the pestles consist, are placed in a row, and are successively raised by cams fixed around a movable axle, so as to correspond with tongues attached to the pestles themselves. The cams are so arranged in three spirals that each pestle shall give three blows during each revolution, and as soon as the first in the series has been released from its cam, and begins to fall, the second cam of the same spiral comes in contact with the tongue of the next pestle; and so on until each has successively struck a blow, when the first pestle is again caught by the first cam belonging to the second spiral, and another series of rapid blows is given. The size of the iron stamp-heads varies according to the nature of the mineral to be broken; but their general weight is from three hundred to four hundred pounds.

In some of the more modern stamping-mills, both the axles and pestles are of iron; and a great improvement in the method of lifting the pestles has been recently effected by Mr. WALKER, of London, who substitutes a series of endless chains for the axle, and thereby increases the height of the fall of the pestles to any required extent. This arrangement is shown in Fig. 220, where A A A represent three of the pestles, while the top of the fourth is nearly on a level with the collar through which they pass; and B denotes the endless chains revolving on the axles, C, D. When motion is given to the machine, the pestles are successively raised through the whole distance from C to D, by projecting links on the chains, which are caught by tongues on the pestles, and these tongues are so arranged that each of them may in rotation be raised and released, as in the case of the spirals already described. A rapid succession of blows is thus struck; and each of the pestles when released falls on the mineral placed below with its whole weight, to which much additional force is given by the impetus acquired in descending through the space, D C.

Fig. 220.



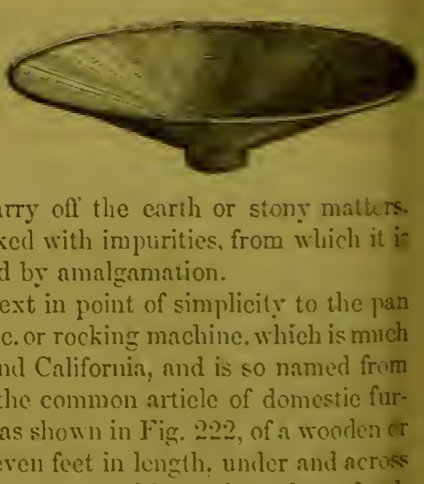
In Mr. WALKER'S arrangement, as in the older stamping-mills, the minerals to be pounded are placed in a large wooden trough, in which are openings provided with sieves, or strainers, made by punching small holes in thin sheets of iron. The pulverized ore is carried through these sieves by a current of water admitted into the trough, which is then conducted over an inclined table, F, set in motion by the chain, E. The heavier and richer portions accumulate on this table, whilst the lighter are washed away into a series of reservoirs, in which they subside in the order of their specific gravity. The machine may be worked either by the hand or by steam or water power.

Grinding.—If it be deemed desirable to reduce the ore to a still greater degree of fineness, any form of apparatus, commonly used for grinding, may be employed. In Mexico the sands obtained from the stamping-mills are afterwards ground, with water, in a machine similar to the common mill-stone. Edge-stones, resembling the apparatus represented in Vol. I., Fig. 97, are also employed for the same purpose. It is necessary, however, that the grinding-mills be either of iron or granite. In the stamping-mill, the ore is already reduced to the state of sand; and, therefore, the further pulverizing, if thought necessary, is usually associated with the operations of washing and amalgamating.

WASHING.—It has been stated, that the greater portion of the gold is obtained from the alluvial soils or sands, on which nature has already performed the operation of crushing or pulverizing the rock. In general, therefore, the washing process is that with which the gold-digger commences; and this, indeed, together with the labor of extracting the soil from the pit, or from the bed of the stream or river, is the only operation usually resorted to for procuring the gold dust or nuggets which are sent from Australia and California. At the same time, the further process of amalgamation, when it can be conveniently employed, extracts the auriferous particles more thoroughly. These two processes—washing and amalgamation—which now remain to be described, are equally applicable to the pounded or pulverized rock, and to the auriferous soils which constitute at present the chief source of the supply of gold. The absolute necessity of washing the soil, to procure the precious grains, even when amalgamation is subsequently resorted to for more effectually extracting the metal and removing impurities, teaches the great importance of opening the pits or diggings in a situation where an ample supply of water can be obtained.

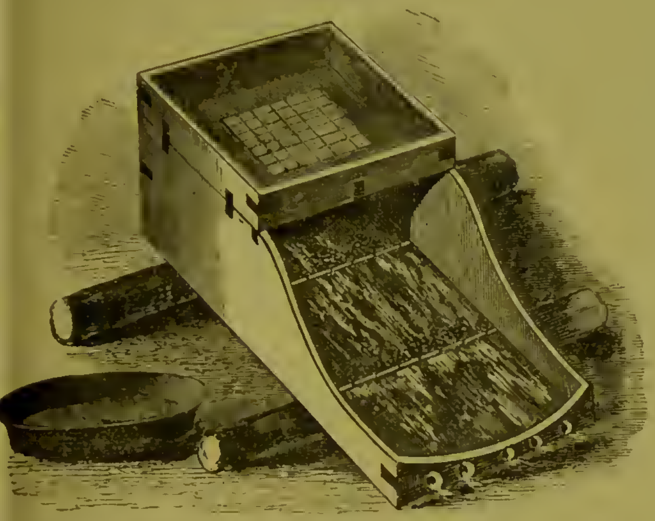
Hand-Washing.—The operation of hand-washing, which is the simplest method of separating the gold dust or grains from the soil, in a state of greater or less purity, has been already described. This method is extensively practised in South America, and the instrument employed is a round iron or zinc pan, Fig. 221, shallow at the sides, but sinking into a deep cavity in the middle, where the heavy particles of the gold accumulate, during repeated washings, which carry off the earth or stony matters. The gold is still mixed with impurities, from which it is ultimately separated by amalgamation.

Fig. 221



The Cradle.—Next in point of simplicity to the pan or basin, is the cradle, or rocking machine, which is much used in Australia and California, and is so named from its resemblance to the common article of domestic furniture. It consists, as shown in Fig. 222, of a wooden or tin trough, six or seven feet in length, under and across the bottom of which two curved bars of wood are fixed, to serve as rockers. Sometimes it is suspended by ropes from a cross-bar, supported at each end by two poles. The cradle, whether suspended or resting on the ground, is made to have a slight inclination from one end to the other, to allow the water to run off. At the upper end is placed a sieve, or coarse grating, on which the sand to be washed is charged; and the interior of the bottom of the vessel is provided with a few transverse bars, to arrest the heavier particles in their descent, while the water and lighter matters flow off. Four men are required to work this apparatus efficiently—one to dig and collect the auriferous sand, another to carry it to the cradle, and deposit it on the grating, a third to rock the trough, and a fourth to attend to the supply of water, and the uniform washing of the material. The grating intercepts the stones and coarser gravel; the earthy matters, containing the particles of gold, pass through; and the latter, with the heavy ferruginous sand, are arrested by the transverse bars, while the lighter portions are carried down by the water to the lower end, which is left open, or where a perforation is made to allow the current to escape.

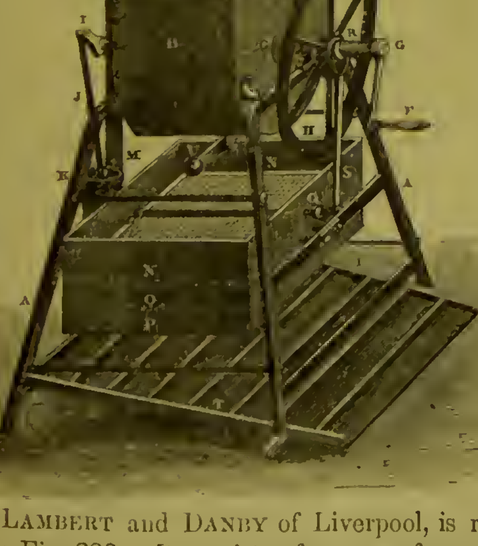
Fig. 222.



After continuing the operation, with repeated charges of the auriferous sand, during a sufficient period, which will vary according to the richness of the material, the concentrated ore which has accumulated behind the bars of the cradle, is collected in a tin pan, shown in the same figure, and after being dried in the sun, the lighter impurities still remaining are removed, by blowing strongly on the mixture with a pair of bellows or otherwise.

Gold-Sifter.—A more refined apparatus, for washing and sifting the auriferous ore, which was registered by Messrs. LAMBERT and DANBY of Liverpool, is represented in Fig. 223. It consists of an open frame, A A, carrying a receiver, B B, in which is a revolving barrel, set with a series of pins, D, working in gear with other corresponding pins, which are made fast in the receiver. The pin-shaft, G, which carries a fly-wheel, H H, is driven by the winch F. The other end of the shaft works a crank, I, from which a connecting-rod, J, passes down to a pump, K, for supplying water through the pipe, M M, to the working-chamber. Beneath the latter is a box, containing three separate sieves, N, O, P, of graduated fineness, and made to oscillate by a lever arm at Q, acted on, through a rod, S, by an eccentric, R, on the shaft, G. At the foot of the frame is an incline, T, for running the water away into the reservoir—strips of wood being set across it, to arrest any small particles of gold which may escape through the last sieve. At U is a valve, beneath the receiver, B, for discharging the agitated mass upon the sieves.

Fig. 223.



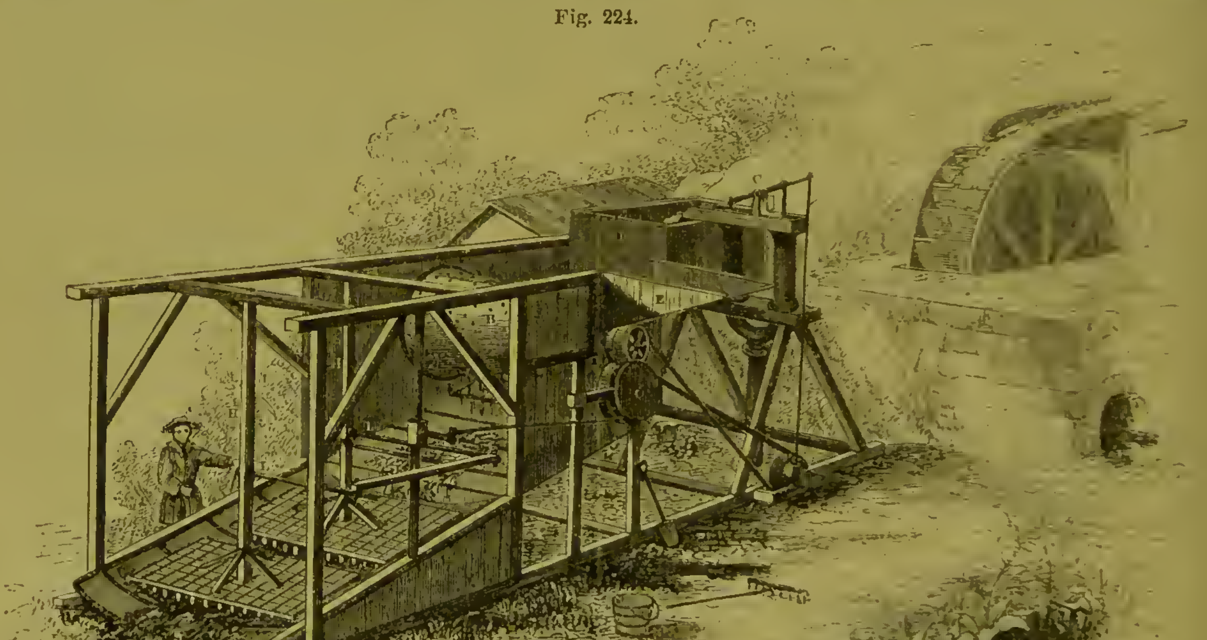
This is a very complete and easily-worked machine. By the simple turning of the winch handle, not only is water supplied in abundance, either from a river or cistern, but the mass is well comminuted, intimately mixed with the water, and reduced to an impalpable slime by the action of the pins, D; so that when accumulated in sufficient quantity to force a passage through the valve, U, the great body of the mixture readily passes through the sieves, and flows away into the reservoir, leaving only the grains of gold and other hard substances which cannot penetrate the meshes, while the finer particles of the precious metal, or what may be termed the gold dust, collect by their superior gravity behind the transverse bars of the incline, T. The series of graduated sieves is important for assorting the particles of gold, and the stony or earthy matters with which they are mixed, into grains of different sizes—the product or contents collected in each sieve being nearly uniform. This greatly facilitates the ultimate washing; for when the grains of an auriferous mixture are of different sizes, the smaller surface of one fragment, in proportion to its weight, compensates in some measure for the greater density of another grain, and thus causes it to assume a position in the series of deposited layers, to which, by its constitution, it is not entitled. This difficulty is found to constantly occur in practice; and it is with the view of obviating it as much as possible that care is taken, in the best machines, to separate, by means of sieves, into distinct parcels, the fragments which have nearly the same size.

Methods of Washing in Brazil.—In Brazil, the excavations and river-washings are entirely conducted by negroes, who are furnished with a large wooden bowl, about two feet in diameter, and nearly one foot in depth; as also with a leathern bag, which is tied before them, for the reception of the particles of gold dust collected, after repeated washings, in the bottom of the bowl. Sometimes, however, the final washing of the auriferous sands is conducted in long shallow troughs, the bottoms of which are covered with coarse baize, or with skins tanned with the hair on, and placed with the grain against the current of water. The baize, or skin, is at short intervals removed from its frame, and beaten over a shallow tank, containing water; it is then carefully washed in the same vessel, until every particle of the gold is removed, after which it is replaced in the trough for receiving the auriferous sands, already partially washed. To obviate the inconvenience of so frequently removing the skin or cloth from the vessel in which the washing is conducted, an endless web of the same material has lately been introduced, which is made to move by means of rollers impelled by the water-wheel employed for stamping the ore. The motion communicated in this manner is opposite to that of the stream of water flowing over the table; and while the upper portion moves upon this table, extended between the two rollers, collecting, in its progress against the stream, the particles of gold, the lower or returning portion hangs down loosely, and is drawn through a vessel of water, in which the gold is washed off and collected.

Methods of washing in Hungary and the Ural.—In Hungary and the Ural the methods of washing are various, but the principle generally adopted is that of inclined troughs or tables, traversed by transverse grooves—a principle adopted in the cradle, and almost all other washing-machines. On the large scale, however, these inclined tables may be compared to the apparatus for washing coal, represented in Fig. 74, at page 95 of this volume. The sand to be washed is placed in the first groove of the series, and is there exposed to a current of water, until the gold, mixed with a portion of ferruginous sand, alone remains in the furrows. The concentrated ore is then removed into flat wooden basins, in which the impurities are gradually separated by repeated washings, or these may be removed at once by amalgamation.

Among the different methods adopted in the Ural districts, there is one by AGTÉ, in use at Alexandrowsk, which is precisely similar in principle to that above described, though somewhat more complex in the arrangements. These are represented in the annexed engraving—Fig. 224—where B is a conical cylinder of sheet-iron, about eight feet in length, and having a mean diameter of about three feet six inches. The cylinder is pierced with holes of about half an inch in diameter, and is fixed on a spindle communicating by a train of wheels and shafts, with a water-wheel, horse gin, or any other prime mover, from which it is capable of receiving a rapid rotatory motion, so as to make from thirty to forty revolutions in a minute. A crank on the shaft which communicates motion to the cylinder, works the double pump, C, at the back of the frame, which raises water from a well or some other convenient reservoir to the cistern, D, and from this it is conducted by pipes into each end of the cylinder, B. The ends of the cylinder are open, and the pipes are so arranged as to diffuse the water pretty equally over its interior surface. Nearly on a level with the top of the arrangement is a line of rails, on which the auriferous sands are brought in wagons to the hopper, E, from which they fall into the smaller end of the revolving cylinder. The latter by its centrifugal action ejects through its numerous perforations the water and finer particles of sand and gravel, which are received upon the inclined platform below, whilst the larger fragments are carried down to the under end of the cylinder, and there fall into a box which does not appear in the engraving. Any gold nuggets which may be mixed with these fragments, being well washed and burnished in their gradual progress through the cylinder, are now readily perceived and picked out. The platform, which receives the water and auriferous sand expelled through the holes in the cylinder, is provided like the cradle, the sifter, and the arrangement last mentioned, with numerous cross bars, for the purpose of checking the current, and arresting the heavier particles of the ore: and after traversing this platform, the current descends to a concave table or tye, G, which is also furnished with a series of wooden bars, at intervals of two or three feet. The sands which have arrived at this part of the machine are kept constantly stirred or agitated by square frames carrying blunt iron knives, and suspended, pendulum-wise, by vertical bars, H H, from a wooden axis above the tye, turning on gudgeons, and placed in the direction of its length. The frames are made to fit into the cavity of the tye, and a swinging alternating motion is given them by means of the rods, L L. In this way the sands are well stirred; and while the heavier or

Fig. 224.



richer portions are retained and accumulated behind the check-boards, the lighter materials are carried away with the current at the lower end, G, of the tye or buddle, from which, if not sufficiently impoverished, they are received on a fresh series of tables, furnished with similar agitating apparatus, and are finally allowed to pass off. This machine is able to operate on two hundred tons of alluvial sand in the course of an ordinary working day of ten hours, with the labor of twenty men and six boys, including ten men for removing the waste, if in a level country, without advantages for otherwise clearing it away.

The partitions in the bottom of the tyes are ribs of two inches high and two and a half inches wide, held by screw-bolts and nuts, and are removed every now and then for the washing out of the concentrated auriferous sand. This is done the more frequently in proportion as the sands are richer in gold.

Fine Washing.—The gold obtained from all the preceding operations, is still so much mixed with sand and other substances, as magnetic iron, pyrites, *et cetera*, that it requires to be further concentrated, either by additional washing or by amalgamation. The powder collected in the buddles or tyes is commonly of a grey color, and is termed *grey schlich*. By the cylindrical machine above described, the original ore or auriferous sand is concentrated to about three tons of schlich for every two hundred tons of the crude material employed. For its further cleaning and concentration by washing, it is treated on uncovered tables or frames, seven to ten feet long, by three or four broad, and divided into an upper and lower part by a lath nailed across the bottom. Also, across the upper part, are fixed two boards, which regulate and equalize the flow of water. The schlich to be washed is placed upon the upper division, and the workman, standing upon the frame in wooden shoes, mixes the sand with the water, and gently moves it against the current, towards the head of the arrangement, with a small wooden hoe or heath-broom. The gold thus arranges itself chiefly near the head-board, and when a certain amount is collected, he rakes it with his hoe or broom, just strongly enough to draw down the earthy particles over the lath to the lower division, without disturbing the heavier and richer deposit. This delicate operation requires skill and dexterity, and must be continued till all the coarse fragments are removed, after which the flow of water is reduced. The workman, by light brushing, raises again all the slime which may still remain, and as much as possible of the magnetic iron ore, and takes up as the product of his manipulation the *black schlich* which is left. The upper department of the box being thus cleared, he now brings upward that which has settled in the lower part, and passes it once, twice, or thrice, through the same operations. This process, for which the most skilful and experienced workmen are required, is termed *fine washing*. The black schlich or ore thus concentrated is dried, and is freed from a further quantity of magnetic iron, by the use of an artificial magnet or a piece of loadstone.

The *gold troughs* used in Hungary and Transylvania for the final washing of the powder or schlich obtained from the cloth-covered tables already alluded to, as well as the process of washing, are similar to those just described. In these countries a broom of heather or birch is generally used instead of the hoe; and in Transylvania the troughs, which are of larger dimensions, are fitted with two traps in their channels, into which the different qualities of schlich are swept at different stages of the process. Even after this fine washing, the resulting products are sometimes further concentrated in the bowl or washing-pan, and so reduced to a state fit for melting, or they are subjected to the process of amalgamation.

AMALGAMATION OF GOLD ORES.—The greater part of the gold of commerce is imported in the shape of dust, or small grains, extracted from the auriferous soil by the simple washings above described, and brought, by a frequent repetition of that process, to a state of sufficient purity to be immediately melted into ingots, more or less mixed with silver or copper. Sometimes, however, instead of the tedious process required to bring the gold by mere washing to that degree of concentration which is necessary for its subsequent fusion, the purification of the gold by this method is only carried to a certain point, and the operation is concluded by amalgamation, or, in other words, by mixing the partially-concentrated ore with mercury, which seizes on the particles of gold, and thus completely separates and extracts the precious metal from the soil or gangue in which it is found.

It may be laid down as a general rule that amalgamation would be advantageously resorted to in all cases, as the finishing process in those operations which precede the metallurgical treatment of gold. By no other method can the precious metal be thoroughly extracted from the gangue, and so effective is its action, as compared with mere washing, that it has often been applied with success to extract a remunerative return from the refuse or waste sands which have passed through the gold-digger's cradle. Its profitable application, however, will depend on the nature and richness of the auriferous soil. If the gold is abundant, and is found in considerable grains, as in many parts of the recently-discovered gold regions, the greater and most valuable part of it is readily separated, and easily concentrated sufficiently by mere washing. On the other hand, if, as often happens, the gold is diffused through a dense and heavy gangue, in particles so minute as to be invisible to the unassisted eye, it is evident that these particles will float away with the current when the sand or crushed ore is washed on inclined tables, and that their extreme minuteness will counteract the effect of that difference in specific gravity by which it is so easy to separate the larger grains when diffused through a less dense soil. On the whole, therefore, while amalgamation must be applied in all cases where it is desired to extract, practically, the whole of the gold, it is more especially applicable to its extraction from quartz rock, from heavy pyritous ores, and from other descriptions of gangue, through which it is diffused in a state of extreme division. And as the mercury exerts no chemical action, but may be again separated from the gold with little loss, the advantages afforded by the great efficiency of this process are not materially restricted by economical considerations.

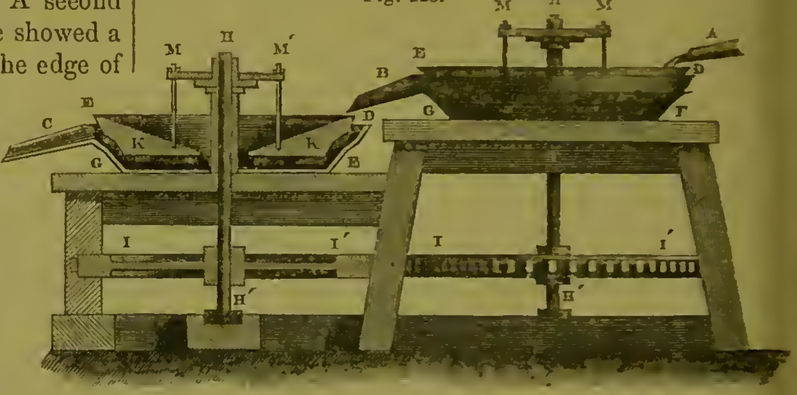
From the nature of the ore which is usually treated by amalgamation, this operation is generally associated with the preliminary processes of stamping or grinding, as well as partial washing. One of the simplest and most primitive methods adopted is described by Mr. W. B. ADAMS as having been witnessed by himself, in the course of a week's trip which he made with a South American *cateador* or gold-mine hunter, for the purpose of acquiring information. When the travellers had passed the extreme limit of vegetation, and entered a narrow ravine between lofty ridges of hills, the cateador began to examine carefully the stones at his feet, which became more and more abundant, till nothing was seen but clay-slate shingle. On the second day, after turning up another ravine, he picked up a stone, which he examined with some attention, and then went on. About mid-day the travellers stopped, and the gold-hunter picked up a fragment of quartz from amidst a great variety of stones. He then placed it on a flat piece of rock and pounded it, and ground it to powder, which he placed in a horn, and poured some water on it, shaking it about with a peculiar motion. A second and a third water were added, and finally he showed a fringe of fine gold on the black horn, along the edge of the quartz sand. No vestige of gold could be observed in the quartz before grinding. Satisfied with the result, he went on tracking the fragments of quartz, till at last the travellers came to the vein, in granite rock. He selected a few pieces, which he put in his wallet, then piled up some stones to mark the spot, and they set out on their return home. In a neighboring valley, he exhibited his stones to a proprietor, whose business it was to extract gold from quartz, and sold him his discovery for the sum of twenty-five dollars.

The mode of extracting the gold was very simple, and is thus described. A vertical running-stone traversed in a circular stone trough. Quartz, broken to the size of walnuts, was thrown into the trough, with several pounds of mercury. A small stream of water trickled into the trough, and flowed over at a particular spot, carrying with it the finer ground particles. At the depth of a foot it fell into a goatskin bag, with some quicksilver in it; thence into a second, third, fourth, and fifth bag, as long as any fall could be obtained. After working several hours, the mill was stopped, and all the mercury collected in a long narrow linen bag. Into this it was forced with a stick, and then the bag was squeezed till all the uncombined mercury passed through, and only the amalgam of gold was left. This was placed on a piece of strongly-heated iron, resting on a brick standing in water. An earthen cupola was laid over the whole, forming a water-joint at bottom, and the neck of the cupola descended into water. Thus the fumes of the mercury, sublimed by the hot iron, were condensed and collected in the water, and the metal saved. The spongy gold, called *pine-gold*, was left on the iron plate.

In Piedmont, where veins of auriferous pyrites have been worked from a very remote antiquity, the extraction of the gold is effected almost entirely by amalgamation. The produce is very variable in different localities, but averages about twenty shillings in value from 150 pounds avoirdupois of the auriferous ore. The amalgamating mills are erected in great numbers on the banks of the various rivulets which traverse the mountains. These establishments usually consist of small wooden buildings, each of which contains few amalgamating machines. They are erected at intervals over the whole length of the valley of Anzasca, from Chamgnaga to Pie di Mulera; and in this valley there are more than two hundred mills procuring a remunerative return from a very poor soil, by the process of amalgamation.

The ore or mineral, when extracted from the mine, is first subjected to a grinding or triturating process in a machine resembling in its action and operation the common millstone, and driven by a water-wheel. When thus reduced to powder, it is carried off by a stream of water to the amalgamating mills, represented in Fig. 225. Whilst held in suspension in the water, it is conducted first to the upper mill by the spout A, from this to the second by the spout B, and so on in succession through the whole series. Each mill consists of a cast-iron basin, D E G F, fastened by screws to the top of a strong frame or table, and fitted in its centre with a tubulature, traversed by the axis H H′, moved by the toothed wheel I I′, and with which revolves a wooden muller, K K, fixed to the upright spindle by the iron collar M M′. This movable part of the mill has externally the same form as the internal cavity of the fixed iron casting, G, in which it revolves horizontally, at the distance of about half an inch from its surface; at the same time it is furnished with several iron ribs, which come nearly in contact with the interior of the casting. The rotating muller is made of hard wood, and is hollowed out like a funnel, in which the auriferous slime accumulates, and gradually penetrates into the interval between its external surface and the bottom or interior surface of the iron basin, from which it flows to the next mill by the spout B or C.

Fig. 225.



In the bottom of the fixed vessel is put about half a hundredweight of mercury, which lies to the depth of about half-an-inch, and when the machine is set in motion, the pounded mineral is constantly agitated and mixed with this fluid metal by means of the iron ribs nailed to the bottom of the muller. The minute particles of gold are thus immediately dissolved and taken up by the mercury, while those which escape combination in the first mill are arrested and retained by the second, third, or fourth of the series.

After working the mills continuously for several weeks, the time required being longer or shorter according to the richness of the mineral under operation, and when the mercury is judged by the workmen to be sufficiently charged with the precious metal, the mills are stopped, and the amalgamated mass is taken out. It is important not to protract the process unnecessarily, otherwise a serious loss of mercury is sustained, occasioned, perhaps, by its partial conversion into a sulphide, which is carried away with the current. The mercury, when drawn off, is washed, and then strained or filtered through a piece of chamois skin, for the purpose of obtaining the solid amalgam, which usually contains about one-third of its weight of pure gold. This is separated from the combined quicksilver by distillation in an iron retort, the beak of which dips into a vessel containing water. The whole of the mercury in actual combination with the gold is thus recovered, and the only loss sustained is that which has been carried away by the current in the shape of sulphide and otherwise. DUMAS states that the loss incurred in this manner is equal to about one-fourth of the quantity employed; but so large a waste must result from careless manipulation.

In the Salzburg Alps, the gold ore is worked in lodes or veins, and the precious metal is separated by three processes—washing, roasting, and amalgamation. It is chiefly in actual *mining*, not in what is popularly known as *digging*, that the latter two operations are brought into requisition. The mineral extracted from the lodes, in the locality above-mentioned, is divided into two classes or qualities—first, that which is so poor in the precious metal that the grains or particles are not visible; and, second, that in which the golden grains may be detected. Both are crushed or stamped; but in treating the former this operation is preceded by roasting, to facilitate its pulverization under the action of the stamps. This roasting, though not practised at all the mining establishments, is useful, not only for the purpose above-mentioned, but also for converting the sulphides and arsenides into fine light oxides.

The mineral, whether roasted or not, having been passed under the stamps and well ground, is washed first on movable inclined tables, and then in wooden hand-bowls. The gold is thus obtained in a state of considerable concentration, and then the work is completed by amalgamation. In the Salzburg country this last operation is conducted in a peculiar manner, and requires a machine constructed with much care, somewhat resembing in its principal parts the common flour mill. The upper mill-stone revolves horizontally in a hollow cylinder, and over it is placed a hopper, which can be depressed or elevated at pleasure. The object of this hopper is to spread over the mill-stone a uniform layer of mineral. Below are placed three iron cylinders, in which the amalgamating mills revolve, with their axes resting on bearings which admit of being raised or depressed according to the nature of the mineral under treatment. Water is admitted by a stopcock into the upper mill, where it is intimately mixed with the mineral into a slime or paste, and from this it descends to the amalgamating mills by an inclined plane terminating in three pipes or gutters, which divide it equally between the three cylinders. From these the fluid amalgam is conducted by a second inclined plane to a washing apparatus.

The process begins with pounding and washing. The mineral, thus pulverized and partially concentrated, is then mixed with a certain quantity of chloride of sodium and thrown into the hopper, from which it descends over the inclined plane into the hollow cylinder containing the large mill-stone. When the hopper is emptied of the first charge, more mineral is poured in till the upper cylinder is full, and then water is admitted, which carries the auriferous slime, so formed, over the second inclined plane into the three amalgamating mills below. Before introducing the quicksilver into the cylinders containing these mills, the machine is allowed to work on the mineral for the space of two hours; the mercury is then added, in quantities of about fifteen to eighteen pounds at a time. The quantity of mercury, water, and mineral introduced should be in the proportion of fifty, thirty, and one hundred; or, in other words, *for every hundred pounds by weight of the mineral, there ought to be fifty pounds of quicksilver, and thirty of water*. In some establishments, a quantity of mercury equal in weight to that of the mineral is introduced, and the work proceeds with all the greater certainty, although the waste or loss of mercury sustained may in this case be more considerable.

In this operation the amount of water introduced is not a matter of indifference. If it be too small, the mixture will be pasty, the motion of the mill will be obstructed, and the ore will adhere to the sides of the cylinders, without undergoing amalgamation. If, on the contrary, the mixture be rendered too fluid, the particles of gold and silver, which are generally found together, will be carried away too rapidly, and in this case also will escape combination with the mercury.

On the other hand, it is evident that an adequate supply of the fluid metal is a point of the greatest importance, as it acts on the gold only in proportion to the extent of surface which it exposes to the mineral. To enlarge this surface, the vessels in which the amalgamation is conducted have latterly been formed like an inverted cone, terminating in a hollow sphere. It is with the same object in view that a rotatory motion is given to the mass; for the centrifugal force thus communicated raises the mercury against the sides of the cylinder or cone, which widens or expands upward so as to increase the extent of surface exposed, and then the mercury falls back again into the mass by its own weight.

Although the numbers given above may convey a general idea of the proportions of the three ingredients to be employed, it deserves to be remarked, that these must be varied according to the nature of the mineral under treatment, and that indeed the quantity of mercury should be proportioned rather to the bulk or volume of the ore than to its weight. The lighter the ore, the more space will it occupy in the cylinders; and as the mercury should rise over the mass, more of it will be required in this case to insure its union with the gold or silver present. If the mercury be in small quantity, the amalgam is not sufficiently fluid, and is partially converted into a dust or frothy substance, which flows away with the water when the latter is allowed to escape from time to time, so that a considerable loss is sustained both in gold and quicksilver. If, on the contrary, the quicksilver be present in excess, the gold combines with it more rapidly and more thoroughly; the amalgam remains fluid, and readily separates from the other materials with which it is mixed. It is therefore by no means economical to stint the supply of mercury.

There are some indications by which a judgment may be formed as to whether the mill is operating in a satisfactory manner. If particles of gold, not amalgamated with the mercury, are observed in the cylinders, this is a proof that the millstone is too high, and does not come into close enough contact with the mineral, in which case the mercury, not being agitated, remains inactive at the bottom of the vessel on account of its superior gravity. If, on the contrary, a quantity of quicksilver-dust and frothy amalgam be observed on the cylinders, this is an evident sign that the former has ceased to absorb the gold, and that more must be added.

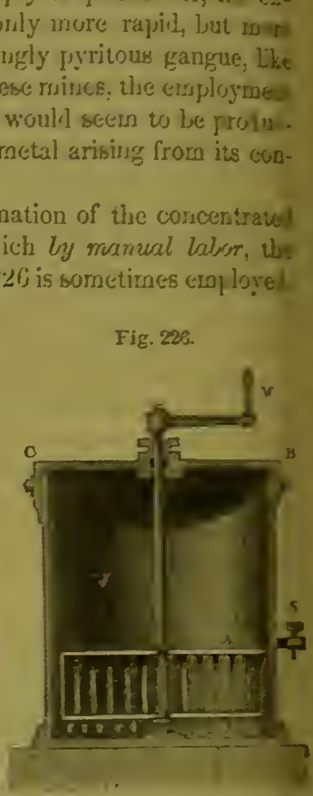
It usually requires about sixteen or eighteen hours to complete the amalgamation. The final washing is then proceeded with, and is effected by a current of water, which carries away the earth, and purifies the amalgam from those substances not combined with the mercury. This operation is performed in a wooden vessel of a conical form, the bottom of which slopes to the centre, and is fitted with a stopcock. A circular movement is given to this vessel, that the mass may be kept in a state of agitation, and the lighter parts carried away by the current of water admitted, while the amalgam falls by its own weight to the bottom of the vessel. This operation is repeated several times.

When the washing is concluded, the next and last step in this process is the separation of the mercury. With this view the liquid amalgam is put into a chamois-skin or woollen bag, and well squeezed. The mercury which passes through the skin or cloth, still retaining a small quantity of gold, is carried back to the cylinders to be employed in amalgamating the next charge. There remains in the bag a semi-solid amalgam of gold, which is put aside for distillation. By wetting the bag which is to be used for straining, a larger amount of amalgam remains, and the mercury which passes through carries with it less gold. When the solid amalgam is very pure, it is rather white in color; but when alloyed with lead or copper it is less so, and does not produce the same crackling noise when crushed or broken. The amalgam, as in the other cases already mentioned, is deprived of its mercury by distillation; or, if a small portion of that metal still remains, it is expelled in the subsequent fusions to which the gold is subjected with a view to its final purification.

The preceding process, which is practised, as already stated, in the Salzburg Alps, presents some peculiarities. The amalgamating mills are somewhat similar to those employed in the Tyrol, but these mills are fed in a different way, and a larger proportion of mercury is used. The last circumstance is highly advantageous, and ought to be imitated in all cases where the nature of the gangue, or mineral under treatment, will admit of it; for, with an ample supply of quicksilver, the extraction of the gold is not only more rapid, but more complete. But, with a strongly pyritous gangue, like that of most of the Piedmontese mines, the employment of a large excess of mercury would seem to be productive of a heavy loss of that metal arising from its conversion into a sulphide.

For effecting the amalgamation of the concentrated auriferous ore or black schlich *by manual labor*, the machine represented in Fig. 226 is sometimes employed. This consists of a species of churn, V, made of sheet-iron, through the lid of which passes a spindle, X, of the same metal, carrying a kind of paddle-wheel, A, which is turned by the winch-handle, W. The bottom of this machine is first covered to a small depth with mercury, and then the concentrated ore is added by an opening at the top in successive small portions, while, at the same time, the whole mass is continually agitated by stirring; and this process is continued till the mercury is judged to be sufficiently saturated with the gold. The amalgam is then taken out and treated in the usual manner, by washing, straining, and distillation.

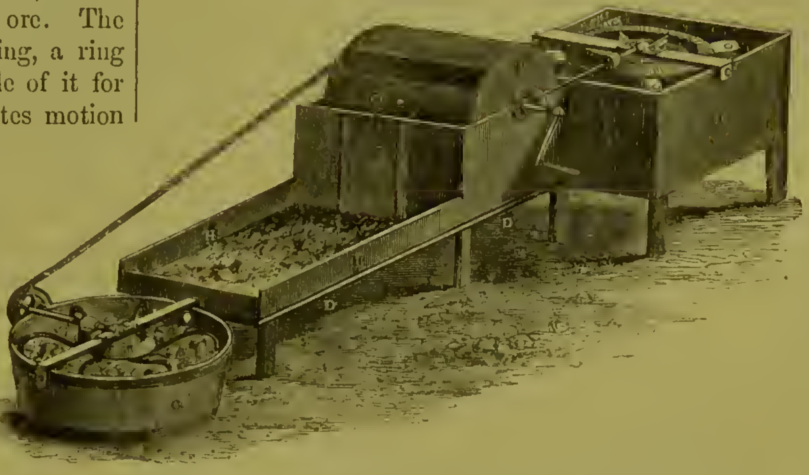
Fig. 226.



It may be stated that the same apparatus is highly convenient for the original washing or concentration of the ore, or auriferous sand, and, when employed for that purpose, is familiarly known as the *dolly-tub*. In this case it is nearly filled with water; and whilst one man keeps the agitator in constant motion, another throws into it, in small portions at a time, the auriferous earth. When the full charge has been thus introduced, the cross-bar, B C, through which the spindle works, is removed, and the agitator is quickly taken out. The materials held in suspension are then allowed to settle according to their respective gravities, and, consequently, the gold, together with all the heavier particles, will sink to the bottom. When these have subsided, the water is drawn off by the stopcock, S; the upper portions of the deposit are cautiously removed and thrown away, while the heavier portions at the bottom are collected for further concentration, either by the hand-bowl or otherwise. But although the dolly-tub may thus be applied to the double use of a washing and amalgamating machine, it is less convenient for the former purpose than the cradle, and other kinds of washing apparatus already mentioned.

Another machine, which is easily worked by the hand, was contrived by Mr. BERDAN of New York, in the heat of the Californian mania, and is known as BERDAN'S Gold Ore Pulverizer and Amalgamator. In this machine, the pulverizing process is effected in a large hemispherical iron vessel, rotating on an inclined spindle, and having within it a weighty iron sphere, connected by a pivot and bearings set in an inclined position loose upon the central spindle of the basin, in such a manner that its gravity causes it constantly to maintain the lowest possible position in the basin, whilst its axis of rotation, owing to the pivot connection, is inclined to that of the basin. The motion thus communicated to the sphere is not a mere rolling, but a species of spiral action, which is said to be very effective in reducing the ore. The basin is made to revolve by suitable gearing, a ring of teeth being cast or fitted on the outside of it for this purpose, and its revolution communicates motion to the sphere. A quantity of mercury is placed in the bottom of the basin, and the ore is reduced to powder entirely beneath its surface, being latterly washed away by a current of water which runs into and out of the basin, and is kept in a constant state of agitation by the motion of the vessel. As heat considerably strengthens the affinity of the mercury for the gold, a new and important feature was introduced into this machine by the employment of a furnace in connection with the apparatus. This furnace or fire-place is of a conical shape, and rests by its lower smaller end on a collar upon the basin-spindle, just above the step. It was stated, though probably with much exaggeration, that while the machines previously employed extracted only from thirty to forty per cent. of the gold in a given quantity of quartz, the most searching chemical analysis was unable to detect any gold remaining in the *tailings* or waste matter from Mr. Berdan's machines, and that these, moreover, were very profitably employed in reworking the tailings from other machines. It does seem probable that the introduction of a furnace to heat the mercury might greatly increase the efficiency of this apparatus, and that the same improvement might be applied with good effect in other machines. At the same time, it is obvious that if caution is not exercised to prevent the heating of the mercury beyond a certain point, a very great loss must be sustained by its volatilization.

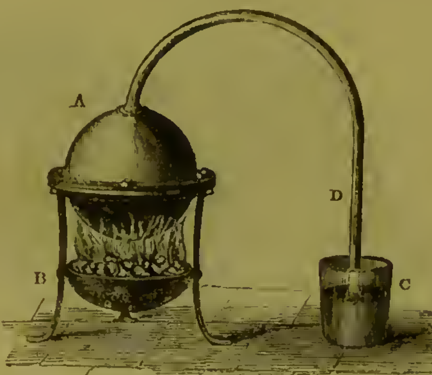
Fig. 227.



Smith's Portable Gold Amalgamator, which is represented in perspective in Fig. 227, also admits of being worked by the hand, and is designed for the use of emigrants, and the proprietors of mines and estates where gold may be supposed to exist. This machine is divided into three compartments. In the first, A, are arranged a set of powerful crushers, and a series of agitating plates, intended for stiff and hard clays; two or three revolutions reduce the matter to a floating pulp, which flows off through a pipe, D D, leading from this part of the machine to the amalgamator, C. The pipe is provided on its lower side with a series of boxes or valves, which can be opened or shut at pleasure, and only that portion of gold passes on to the amalgamator which cannot be detained in these valves. The second compartment, B, is constructed for the reception of the looser earth, and consists of a drum or barrel in which revolves an agitating apparatus. Nothing is allowed to leave this until it is perfectly worked, when the opening in the side of the barrel is turned downward, and all stones and other foreign matters are discharged into the chamber beneath, in readiness for receiving a fresh supply of the auriferous earth. The chamber into which the contents of the barrel are thus discharged is relieved from time to time by raising a sluice; and the floating matter then passes over a long trough, H, provided with check-bars, to empty itself into the amalgamator—all solid particles being, in this case also, arrested in their passage from the washer, while, by a simple arrangement which it is unnecessary to detail, the action of the machine keeps up a constant supply of water. The third portion, C, of the machine, or that compartment which is properly the amalgamator, is so constructed as to expose a large surface of mercury to the action of the floating matter, and by means of washers and balls made of wood, to render it impossible for any portion to escape coming into contact with the mercury. This part of the apparatus admits of being locked up, so that none of the gold can be abstracted without the knowledge of the party possessing the key. The machine requires only two men to work it; but it may also be driven by steam or water, and gives, when properly constructed and managed, very satisfactory results.

Distillation of the Mercury.—When the amalgam has been formed by any of the methods or machines above-described—in all of which the object kept in view is to place the particles of gold in the most favorable condition for coming into contact with the mercury, and combining with it—and when the fluid metallic mass has been washed, and the excess of uncombined mercury strained off, the last operation required in this method of treatment is the separation of the mercury which remains combined with the gold in the form of a semi-solid amalgam. This is performed by distillation at a high temperature, in a cast-iron vessel prepared expressly for that purpose. Different forms may be given to the apparatus, according to the scale on which the operation is conducted; but a very convenient one is that represented in Fig. 228, where A, is a cast-iron sphere or shell made in two parts, and capable of being joined together in the middle by a flange and screws. From the top of the upper hemisphere proceeds a bent iron pipe, D, which dips into water contained in the vessel, C—the whole forming a convenient iron retort. When used, the hemispheres are taken asunder; the amalgam is introduced, and the two halves are again screwed together and well luted with some refractory substance. The retort is then placed on any convenient support over the fire, B, which may be of wood or coal; the heat is gradually raised, and the sublimed mercury, which is conveyed away by the tube, D, is condensed and collected in C. Care must be taken to prevent the end of the pipe from diping too deeply into the water; for if the temperature of the fire happens to fall, a vacuum is produced in the retort, which, if the pipe be too deep, will cause the water to rush up into the globe, and produce an explosion. The end of the pipe is therefore introduced just below the surface of the water, so that if a small portion of the water be drawn up into the pipe, that which remains in the condenser, C, immediately sinks beneath the level of the orifice, and all danger is averted.

Fig. 228.



When the distillation is concluded, which is known by the cessation of any further accumulation of quicksilver in the condenser, this distilled mercury is collected to be used for future amalgamations. The gold which remains in the retort, A, is now comparatively pure; but still contains a mixture of silver, copper, or other metals, in greater or less proportion, according to the sources or localities from which it has been procured. The separation of these, with a view to the obtaining of the gold in a state of absolute purity, will form the subject of the next department of this treatise.

In the meantime, it may be repeated that the amalgamating process is chiefly applied in the working of auriferous veins, or *gold-mining* properly so called, in contradistinction to the much more common method of extracting the gold from drift-beds or stream-mines, by the mere operation of washing. In the former case, the gold, generally in very minute particles, is mingled with various other minerals and rocks, as pyrites, zinc-blende, quartz, *et cetera*, and can only be extracted after the whole has been reduced by stamping, to a very small size—in which state, the gold, often so minute as to be invisible, would be almost entirely carried away by a stream of water. It is here therefore that amalgamation offers peculiar advantages, as the mercury seizes on the gold, however finely reduced, and none of the precious metal is lost—provided the precaution be taken not to pulverize or stamp the ore too fine, when about to be submitted to those preliminary washings which precede the amalgamation. On the contrary, when about to be brought into actual contact with the mercury, the ore or schlich cannot be reduced too small; and hence the importance of actually pounding it, if possible, under the surface of the mercury.

From these considerations it will be readily seen that the process of amalgamation is not only applied with advantage in the working of auriferous veins or lodes, but that it may also be employed to procure a profitable return from the re-working of the tailings or refuse of the Australian or Californian gold-diggers. The Editor has little doubt that the greater part of the abandoned diggings, which have yielded a large return by mere washing, will, in course of time, be worked over again by amalgamation; and, indeed, this *gleaning process*, as it may be termed, has already been applied in many cases with highly satisfactory results. To give an idea of what may be done with poor ores, when system and skill are brought to bear, it may be sufficient to state the average produce obtained from the stamped ores at Schemnitz, in Hungary, in 1842—recollecting that these had to be broken from the solid lodes at depths extending to two hundred fathoms. The total quantity stamped in that year was above forty thousand tons, and the average of the useful metals extracted from fifty tons was: gold, three ounces; auriferous silver, derived from the separating processes, by buddles or tyes, *et cetera*, three pounds three-quarters; lead, similarly obtained, eight hundredweight one-third; the ratio of the gold to the other materials being in this case as one part to half a million. In the case of a particular mine, called Siglisberg, not producing lead with the stamped ores, the ratio of gold was only as one part to seven hundred and sixty thousand; of auriferous silver, one to twenty-four thousand. Now, it is interesting and instructive to compare with this economical extraction of minute quantities from poor ores by the process of amalgamation the produce of the manipulation by washing at the Siberian workings, where a common average of the sands worked to profit is half an ounce in one hundred hundredweight, or fully double the amount last mentioned, and yet even the poorer ores of Hungary yield a remunerative return by amalgamation. It follows, that by the same process many auriferous sands in Siberia, as well as in other countries, which are at present neglected, as being too poor for washing, might be advantageously worked.

Separation of Gold from Arsenical Pyrites.—Another illustration of the importance of scientific knowledge in the working of gold mines, is furnished by the recent application of Plattner's method for the separation of gold from arsenical pyrites, in consequence of which the mines of Reichenstein, in Silesia, which, as already stated, had been abandoned for more than five centuries, were reopened with advantage eight or ten years ago. This successful application of a purely scientific suggestion is due to the skill and enterprize of W. Guettler, of Reichenstein, to whom, in conjunction with Professor Plattner, the inventor, a council medal was awarded at the Great Exhibition of 1851, for a series of specimens illustrating the different stages of the process. The principal agents employed are chlorine and sulphide of hydrogen. The following account of this novel and ingenious process is given in the published reports of the Jurors :—The ore at Reichenstein is an arsenical pyrites, containing about two hundred grains of gold in the ton. The ore is roasted in a reverberatory furnace, surmounted by a large condensing chamber, in which the arsenious acid is condensed as fast as it is volatilized. There then remains, on the floor of the furnace, oxide of iron mixed with a certain quantity of arsenic, together with the whole of the gold. This is placed in a vessel so arranged that a current of chlorine can be passed through it, by which the gold and iron are taken up, and afterwards separated from the residuum by the aid of a certain quantity of water, and the gold is afterwards precipitated from this solution by sulphide of hydrogen. To prevent the admixture of iron at this stage, a few drosses of hydrochloric acid is added to the solution before the sulphide of hydrogen is introduced. The auriferous compound having been separated from the liquor, is washed and heated in an open porcelain crucible, to drive off the sulphur, after which the gold is reduced to the metallic state by fluxing it in the usual way.

This simple and ingenious method, which has made it worth while to reopen the Reichenstein mine, is equally applicable to the vast quantity of refuse accumulated near many other old works.

METALLURGICAL OPERATIONS.—*Fusion.*—When the gold is received from the *gold-washer*, in the shape of gold-dust, or when it has been separated from its ores by amalgamation or otherwise, it has now to be subjected to a series of metallurgical operations to obtain it in a state of perfect purity. The first of these operations is that of fusion with borax, and casting the metal into ingots, by which it is obtained in a convenient form, and freed at the same time from earthy and other impurities. For this purpose, the gold dust from the washings, or the spongy gold obtained by amalgamation, is mixed with a little dried borax, and is introduced into a black-lead crucible, which has been previously heated in a common melting furnace. After the fusion of the metal, a slag, consisting of the grosser impurities, accumulates on the surface; this must be thickened by the addition of a little bone-ash, and then skimmed off. The metal is now cast into bars, by being poured into iron ingot-moulds, which should be previously warmed, and oiled, by wiping the internal surface with a piece of tow dipped in sweet oil. It is an old practice, now discarded by some metallurgists as useless, to add to the metal, when thoroughly melted in the crucible, a small quantity of corrosive sublimate; the contents are then well stirred, and, in consequence of the volatilization of the sublimate, effervescence takes place. That this is attended with no injurious effect seems to have been fully established by a long experience, and that it may even be productive of benefit is probable, by bringing to the surface any extraneous matter which might be detached from the interior of the crucible, and so permitting its removal along with the slag. The crucibles which have been used in a series of such operations, retain a portion of gold, which renders it important to preserve them, with a view to the subsequent extraction of the precious metal by smelting.

SMELTING OF GOLD ORES.—Although the readiest method of extracting the gold from rich alluvial sands is by repeated washings, in the manner already described, and although in the treatment of quartz rock, iron pyrites, and other auriferous minerals, the method involving the tedious operations of pounding, washing, and amalgamation is usually adopted, yet, in the latter case, the same object may be accomplished by direct *smelting*—a term technically applied to a process, or series of processes, by which a metal is extracted, by the agency of fire, from the substances with which it may be combined or mixed in nature. It is well known that by this method iron is extracted from its ore in the blast furnace, and some years ago a Russian gentleman, named ANOSSOW, even proposed to smelt in this manner the auriferous sand of the Ural, alleging that a much larger quantity of gold could be so obtained than by the most skilfully conducted process of washing. His method consisted in smelting the sand with iron, the latter being employed simply as a vehicle to collect the gold, or to perform, in its melted state, the same part as mercury in the processes already described. When the gold was obtained in this state of combination, the mass was exposed to the action of sulphuric acid, by which the iron was dissolved and the gold remained in the insoluble residue. From some experiments which were made at the Museum of Practical Geology in London, it was found that, if it were advantageous on the score of economy, cast-iron might really be so applied; and that when it is melted with gold, an alloy seems to take place, from which the greater part, if not the whole of the gold may be extracted by again melting the alloy in contact with lead, which abstracts the gold. With regard to ANOSSOW's process, experiments were reported to have been made on the large scale, which had perfectly succeeded; but a strong proof of its want of success is the fact that it has never been practically adopted.

Of late years much has been said and written respecting the smelting of what has been called *gold quartz*, or, in other words, the extraction of the metal from the quartz in the furnace. The Editor, therefore, in proceeding to explain the common method of smelting, will assume, in the first place, that quartz or silica is the auriferous ore which it is proposed to subject to this operation. From the well-known infusibility of this substance, it is evident, that mere exposure to the strongest heat of a blast-furnace, without the addition of a flux, would be of no use; for, although the gold would be melted, it would remain in the quartz, and no separation of the precious metal would take place. Even supposing the quartz to be first reduced to powder, the gold is present in too small quantity to separate from the infusible mass, and sink to the bottom. It is therefore necessary to add some substance which, at a high temperature, shall combine with the quartz, and produce a fusible compound, in which case the gold, more especially if combined with some other heavy metal, will, in virtue of its high specific gravity, fall to the bottom of the vessel.

The best flux for silica is carbonate of soda, but this is too expensive to be employed on the large scale. Lime, therefore, aided by the addition of oxide of iron, is usually employed for this purpose. Lime alone, or lime and clay in certain proportions, will combine with quartz at a high temperature, and produce a fusible slag. Oxide of iron alone will also suffice. When practicable, it is desirable to obtain the oxide of iron by roasting auriferous pyrites, such as that found in California or the Tyrol, for then the proportion of gold is increased by that contained in the pyrites. Whatever flux be employed, it is necessary, in the first place, to reduce the quartz to a comparatively fine state of division, otherwise a considerable loss of time and waste of fuel would be incurred in effecting the perfect combination required to ensure the complete separation of the gold. Even in smelting, therefore, the crushing or pulverizing process is not dispensed with. Assuming that lime and oxide of iron are the fluxes employed, and supposing the pulverized ore to have been partly concentrated by washing, these substances are mixed in about equal proportions, and raised to a white heat in a blast or reverberatory furnace. When oxide of iron is employed as the flux, the reverberatory furnace is to be preferred, because in the blast-furnace a considerable portion of the oxide would be reduced, and a corresponding quantity of metallic iron liberated, long before the mixture attained the degree of heat requisite for the combination of the silica with the oxide.

The product of the combination is a fusible *slag* or glassy substance, through which the gold, also in a melted state, tends to sink to the bottom of the furnace. But as the portion of this metal present even in a large quantity of ore is very small, compared with the bulk of the materials through which it is now diffused, it would be difficult to collect it *per se*, without very serious loss, in a crucible, and still more so in a furnace, whether reverberatory or blast. The operation is therefore materially assisted by adding another metal which shall combine with, and absorb, the whole of the gold, and from which the latter can afterwards be easily separated —some metal, in short, which shall serve the same purpose at a high heat, as mercury serves at the ordinary temperature. Of all metals, lead is found to be the best-adapted for this purpose, not only on account of its readily combining with the gold in a melted state, but also as offering peculiar facilities for its subsequent separation from that metal. Lead has, therefore, been uniformly employed in the processes hitherto generally adopted for smelting gold ores. The lead may be added to the mixture of ore and flux, either in the metallic state, or in one or other of its combinations, from which the metal may be set free. The materials most commonly employed to furnish the lead are litharge and galena—the former the protoxide, and the latter the native sulphide of that metal—although the rich slags obtained both from the smelting furnace and ore-hearth are also occasionally used. When litharge is chosen as the medium for the introduction of lead, it must be mixed with charcoal, small coal, or coke-dust, in order to determine the reduction of the necessary quantity of lead to the metallic state; but when galena is used, it is mixed with scrap-iron, for the purpose of combining with the sulphur, and setting the lead free. The lead-slag which comes from the ore-hearth or the reverberatory furnace, is generally the most convenient and least expensive material, as it contains a considerable per-centage of lead, and is readily prepared for use by grinding it to powder under the edge-roll, and mixing it with charcoal or other carbonaceous matters. In this case, also, it is important to add some scrap-iron to combine with any sulphur which may be present in the slag. Whichever of these substances be employed, the lead evolved, under the conditions mentioned, percolates through the mass, and subsiding by virtue of its high specific gravity to the bottom of the furnace, carries along with it any particles of the precious metal it may meet with in its course. The lead is afterwards separated by *cupellation*—a process to be explained shortly.

Smelting with Iron Pyrites.—Instead of directly employing lead as the means of concentrating the gold ores, a method has been practised in Hungary, in which iron pyrites, generally itself containing a portion of gold, is used with economical effect for the same purpose. When this mineral is heated to a certain temperature without access of air, it loses exactly half of its sulphur, and becomes converted into a fusible sulphide of iron, such as is produced by bringing a roll of sulphur in contact with a bar of iron raised to a white heat. Let it be assumed, therefore, that the ore consists of a mixture of auriferous iron pyrites and quartz, and that this ore is mixed with the appropriate flux for the quartz, as already described, and exposed to the requisite heat,—in this case a slag will be formed, and the sulphide of iron will unite with the greater portion of the gold present, forming a heavy regulus, which will subside to the bottom. The stratum of sulphide of iron thus found beneath the surface of the slag and scoriæ produced by the fusion of the earthy and siliceous gangue, is technically termed a *matt*. If this matt, containing the gold, be now roasted, or *oxidized by heating it with free access of air*, whereby it is deprived of a further portion of its sulphur, and the product be mixed with a fresh quantity of crude auriferous pyrites, and smelted again, a second matt will be obtained, which will contain the gold from the first and second charges of the auriferous ore. This process may be repeated a third, fourth, or any number of times, until the precious metal has been sufficiently concentrated in the substratum of sulphide of iron to admit of its profitable extraction. The last matt, containing the whole of the gold which has accumulated from the successive charges, and brought, therefore, to any required richness, is then fused with metallic lead, litharge, or with a mixture of galena and metallic iron. The gold is abandoned to the liberated lead, from the top of which the impoverished sulphide may be readily skimmed off.

By this process, the gold is obtained in a more concentrated form, or mixed with a smaller proportion of lead, than when the latter is used directly as the means of separating and collecting it from the smelted ore. Still as the lead must be used for its final separation from the ore in all cases—even when the gold has been concentrated by washing and amalgamation—the employment of the iron pyrites in the manner above-described is only attended with advantage when it constitutes part of the ore itself, or when it can be readily and cheaply procured in sufficient abundance. When it forms a principal ingredient in the ore, it is manifestly highly advantageous, in point of economy, to employ it as a vehicle for the concentration of the precious metal, while it contributes at the same time to increase the amount of the product.

Patent Smelting Process.—Some years ago a patent was secured for another smelting process, invented by Mr. LONGMAID, which consists in separating the gold from the quartz or siliceous ore, by introducing plates of wrought-iron into the melted mass. The quartz is first crushed to a fine powder, and fluxed with a mixture of lime and oxide of iron, as usual. Into the fused mass thus obtained, plates of wrought-iron are from time to time introduced, and withdrawn when their surface is found to be coated with a film of gold. The plates are then plunged into a vessel of melted lead, which dissolves off the precious metal, and afterwards again put into the furnace. This process is constantly repeated till the whole of the gold is extracted from the ore, and it is said to be thus obtained both more economically, and in greater proportion, than by the usual process of washing and amalgamation; but the Editor is not aware that this method has yet been extensively practised.

CUPELLATION.—The next metallurgical operation is the extraction of the gold from the lead, and this has been performed from the most remote antiquity by a process termed *Cupellation.* This process, which is very simple in principle, is, at the same time, one of the most elegant chemical operations ever invented. It depends on the circumstance that when silver and gold are exposed in a state of fusion to the action of the air or oxygen, they neither give off perceptible vapors nor are sensibly oxidized—they remain, in short, unaffected; whereas, under similar circumstances, lead and almost all the other metals are oxidized with greater or less rapidity. There is also an important peculiarity connected with lead, which renders it the only metal, excepting bismuth, applicable to the process of cupellation. This peculiarity consists in the circumstance, that the white oxide of lead, known as litharge, is fusible at a bright red heat, and in this state liquefies and absorbs into its mass any other metallic oxide with which it may happen to be in contact, but which, without the influence of the oxide of lead, would remain unliquefied by the heat. For example, if the oxide of copper be present, this oxide, which is a fixed infusible substance at the temperature of a common furnace, is taken up by the melted oxide of lead; and if the latter can be separated from the gold and silver, the oxide of copper will be expelled along with it.

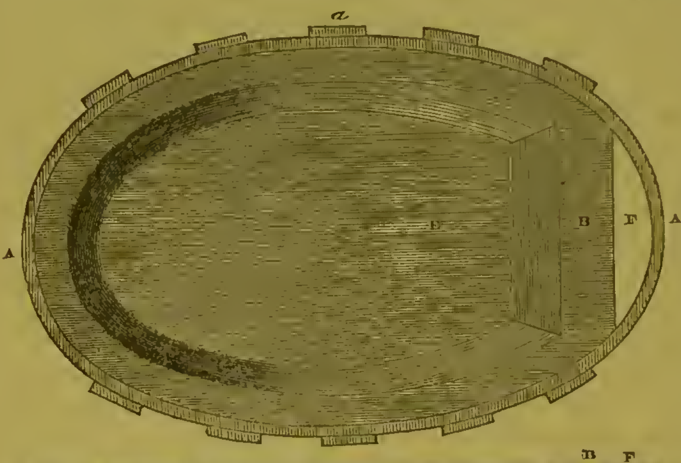
This separation may be effected by different methods, but particularly by means of bone-ash, which possesses the peculiar property of absorbing the melted litharge, even when mixed with a certain proportion of other oxides, whereas it remains impermeable to the unoxidizable metals. Hence, if a vessel be formed of pounded and compressed bone-ash, and into this vessel a compound be introduced consisting of a mixture of litharge or oxide of lead, oxide of copper, and native gold, which always contains a certain proportion of silver; and if this mixture be exposed to the powerful heat of a furnace, the whole will be reduced to a state of fusion; the oxide of lead, in melting, will combine with and dissolve the oxide of copper, and both will be absorbed by the bone-ash, while the mixture of gold and silver will remain in the vessel, melted by the heat, but otherwise unaffected. Hence it follows that gold and silver, or a mixture of the two, may readily be deprived of copper or any other oxidizable metals by cupelling them with oxide of lead. For this purpose it is not necessary to employ the oxide itself in the first instance. When metallic lead is heated to a temperature above its melting point, it rapidly combines with the oxygen of the air, the product being in the first place yellow oxide of lead, which appears as a scum on the surface; and when the temperature is raised to about bright redness, this oxide is converted into litharge or the white fusible oxide, which immediately melts. Pure copper requires not less than sixteen or seventeen times its weight in lead to be absorbed in the manner above-mentioned.

A vessel of bone-ash, formed for this purpose, is termed a *cupel* or *test;* and in using such vessels for *assaying,* the absorptive power of the cupel is the only agency employed to separate the gold from the lead and other oxidizable metals, as will be explained afterwards. It is otherwise in cupellation on the large scale; in this case the cupel is soon saturated, and the greater part of the litharge is expelled by a different method.

The English method of cupellation or refining is as follows:—A piece of bar-iron, about half an inch thick and four inches deep, is bent into the form of an oval hoop, and the ends of the bar are welded together. The greater diameter of this hoop, which is destined to form the containing circumference of the cupel or test, may be about four feet, and its lesser two feet six inches; but the dimensions vary considerably according to circumstances. On the lower part of the hoop are fixed a series of four or five flat bars of iron, arranged parallel to each other in the direction of the short diameter. The first of these is placed about nine inches from one end of the oval, and the others at about equal distances between this bar and the other extremity. The hoop is then placed with the cross-bars downwards upon a solid floor, and a quantity of pounded and sifted bone-ash is beaten firmly into it with a mallet or rammer until it is entirely filled, or the bone-ash is level with the upper edge of the hoop. The bone-ash employed for this purpose is mixed with about one-tenth, by measure, of fern-ashes, or one-fortieth by weight, of American pearl-ashes, and moistened sufficiently to become coherent by pressure. The fern or pearl ash has the property of giving greater consistency to the bone-ash when heated. When the hoop or frame has been well filled with this mixture and solidly beaten down, the surface is carefully scooped out with a trowel all round the centre, so as to form a shallow concavity of about two inches and three-quarters in depth, leaving a wall of bone-ash all round, about two inches in thickness at top and three inches at bottom, except at one end, where a thickness of five inches is left; whilst the thickness of the sole itself is reduced to one inch above the upper surface of the iron cross-pieces. At that end of the test where the wall was left five inches thick, and which is termed the *breast*, a segment of the bone-ash, contiguous to the hoop, is removed.

This apparatus is represented in Figs. 229 and 230, of which the former is a plan, and the second a longitudinal vertical section of the cupel or test. In these drawings, the letters A A denote the iron hoop; *a a*, the transverse bars; E indicates the cavity in the bone-ash; B, the breast; and F, the space where the bone-ash is removed between the breast and the iron.

Fig. 229.



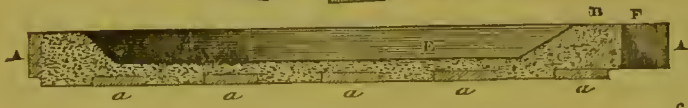


Fig. 230.

When fully prepared, the test is allowed to dry, and is then placed in a furnace, constructed in all respects like a common reverberatory, except that a space is left open in the bed of the furnace to receive the test, and that the long axis of the arch is very short. The test, in fact, forms the bed of the furnace, in which it is adjusted with the long diameter transversely. It is supported in its place by an iron ring built into the masonry, or by iron bars placed underneath, between the two walls of the furnace. The fire-place of a cupelling furnace is usually about two feet in breadth, and two feet six inches in length. This is separated from the body or bed of the furnace by a fire-bridge eighteen inches in breadth, so as to allow the flame and heated air to pass directly over the surface of the cupel, from whence it escapes through separate flues into a high chimney. At the side of the furnace opposite to the breast of the cupel, the nozzle of a pair of large double bellows, or a fan-blast, is introduced.

When the cupel is inserted and the furnace lighted, the heat must be applied in the first place with much caution; for the cupel or test, if exposed suddenly to a high temperature before it has become sufficiently dry, is liable to split and fall to pieces. In the meantime, the lead containing the gold and silver, and which, from this circumstance, is termed *rich lead*, is brought to a state of fusion in a cast-iron pot, set in brickwork at the side of the furnace; and when the test has been cautiously raised to a cherry-red heat, the rich lead is laded into it till nearly full. Oxidation now proceeds rapidly. At first the lead becomes covered on the surface with a yellow or grayish dross; but on further raising the heat, the surface of the bath uncovers, and a film of melted litharge begins to appear. Part of this litharge sinks into the bone-ash of the test, which it soon saturates. The blowing apparatus at the back of the test is now set in motion, and forces the litharge as it forms forward to the breast, B, across the surface of which a channel is cut, through which the litharge begins to flow, and runs over at the end through the vacant space, F, into a movable iron pot, placed on the floor for its reception. By this means the oxidized lead is prevented from coming in contact with the iron frame of the test, on which it would exert a powerfully-corroding action. The current of air introduced at the back of the cupel not only assists in clearing away the litharge, but readily supplies the amount of oxygen necessary for its rapid formation. In proportion as the litharge flows away, more of the melted lead is gradually supplied to the test, which is done by lading it into a channel from the pot outside the furnace.

After a certain period, the channel first formed in the breast, B, becomes much corroded; it must then be stopped, and a second and third channel successively formed for the same purpose. In this manner the operation may be continued until six or eight tons of the rich lead have been refined on the same test. Sometimes, however, two tests are employed, the first to concentrate the lead, and the second to separate it entirely from the precious metals. In this case, when the lead has been so far concentrated in the former that the whole of the gold and silver contained in the alloy may remain in combination with only two or three hundredweight of that metal, a hole is made through the bone-ash of which the bottom is composed, and the concentrated lead is received into a pot which is placed below. The tapping-hole is then closed with a pellet of moistened bone-ash, and a fresh charge of the original rich lead is concentrated in the same manner. When a sufficient amount of concentrated lead is thus accumulated to yield, as ascertained by assaying a small portion, from one to two thousand ounces of the precious metals, the whole is again melted down, and submitted to a second cupellation in another test, in which the operation of refining is completed.

Towards the conclusion of the operation some striking appearances are presented. As soon as the last portions of lead are removed, the liquid alloy of gold and silver in the cupel suddenly assumes a bright and resplendent surface; and, if the gold present is mixed with a considerable amount of silver, the surface of the mass, as it cools, is suddenly thrown into agitation; cones, or little craters, sometimes several inches in height, are thrown up, from which oxygen gas escapes with violence, projecting particles of silver with considerable force. This phenomenon is termed *spitting*, or sometimes *vegetation*, from the beautiful arborescent forms which are presented; and arises from the circumstance that metallic silver, when melted, has the property of temporarily combining with or absorbing much more than its own volume of oxygen, which escapes or is ejected with violence at the moment of solidification. For reasons especially connected with the final process of *parting*, and which will be afterwards explained, there is almost always introduced into the alloy, before cupellation, a comparatively large amount of silver, so that the phenomena above described are almost uniformly observed at the conclusion of that process. Even in the cupel, the presence of a considerable proportion of silver is important, for the purpose of diluting the gold, and so diminishing the chance of loss.

After the cupelling, the test, with its cake of alloy of gold and silver, is withdrawn from the furnace; the metallic mass is removed and cleaned from external impurities; and the bone-ash, saturated with litharge, and any other oxide that may be present, is knocked out and preserved for subsequent treatment, as it contains not only a considerable quantity of lead in a state of oxide, but also a small proportion of silver.

On the Continent, the process of refining is conducted without the use of a cupel, properly so called. No bone-ash is employed. The test, if it may be termed so, is the bed of the furnace itself, which consists of a kind of marl, firmly beaten down into a circular cavity, sloping from the sides to the centre, and allowed to dry. The roof of the furnace, which consists of a flat dome of bricks, built in a strong circular hoop of bar-iron, is movable by means of a crane. Several tons of lead are introduced at once, and after the roof has been replaced, the blast is transmitted through one or more apertures in one side of the furnace; the whole mass of metal is then worked off continuously, without any addition, till the lead is entirely removed, and the alloy of gold and silver is left fine.

Parting.—The final operation of separating the silver from the gold, is termed *parting*, and is generally performed in this country by means of nitric acid, which dissolves the silver, without attacking the gold. On the Continent, the same effect is produced with *hot sulphuric acid.* In assaying operations, nitric acid is always employed, and therefore the precautions necessary to be observed in this case will be fully explained in connection with the subject of *assaying.* In the meantime, the process with sulphuric acid, as practised on the Continent, will be first detailed.

1. *By Sulphuric Acid.*—It is only of late years that the use of sulphuric acid for this purpose has been generally introduced on the Continent, in consequence of its being now manufactured so much cheaper than nitric acid, which was formerly the only acid employed. The operation is performed in a very simple manner, and if any copper has been left in the alloy, it is separated along with the silver. It is true that the copper should be entirely expelled by the process of cupellation; but, as this process is practised on the Continent, a considerable amount of that metal often remains in the mixture; and its presence is by no means injurious, but is rather useful, in the subsequent operation of parting with sulphuric acid. It is true that if too much copper be present, a sulphate is produced, of which only a limited proportion will dissolve in the concentrated acid. The proportion of gold also must be less, as compared with the amount of the silver, than when nitric acid is used. Experience has shown that the alloy should not contain more than one-twentieth part of copper; and that the proportion of the gold to the silver should not exceed one-fifth; whereas, with nitric acid, it is sufficient if the weight of the silver amount to about three times that of the gold.

When the silver is not already present in the required proportion, which is never the case with native gold, the requisite excess must be introduced; for, when the amount of gold exceeds the proportions above-stated, the particles of silver are so enveloped in that metal as to resist for a long time the action of the strongest nitric or sulphuric acid. In the process of assaying, the proportion of rather less than three parts of silver to one of gold is very closely adhered to, for reasons to be afterwards mentioned; but in operating on the large scale with sulphuric acid, the proportion of the gold to the silver may vary from one-fifth to one-tenth, without inconvenience; and Dumas states that the operation may be conducted with profit when the ratio of the gold to the silver does not exceed 1 : 1000.

The alloy being prepared in the requisite proportions, which is generally done by introducing the excess of silver before cupellation, is melted in a crucible, and granulated by pouring it into cold water. For one part of the granulated alloy, three and a-half parts of concentrated sulphuric acid are taken, and the mixture is put into a platinum vessel, which is then introduced into the furnace. The vessel should not be more than two-thirds filled, to guard against the effects of effervescence, which might throw out part of the liquid. It is then covered with a platinum hood, provided with a beak or tube for conveying the gases and vapors into a condensing apparatus. The capacity of the platinum retorts varies, and there is usually an assortment of different sizes, for treating alloys of different qualities, without the necessity of mixing them. After two or three hours' boiling, varying the time according to the size of the retorts, the silver, and any copper that may be present, are completely dissolved.

On the first application of sulphuric acid to this purpose, the operation was performed in iron retorts. Vessels of platinum were afterwards introduced, as this was considered to be the only metal which could perfectly resist the action of hot and concentrated sulphuric acid. Afterwards, however, the enormous expense required for a complete assortment of platinum retorts, induced the attempt to return to the use of iron, and successful experiments were made by M. Tocchi, which proved that iron retorts might be safely employed, though platinum is still in use in many establishments. It was found that the very concentration of the acid presented, of itself, an obstacle to the precipitation of the silver or copper by the iron; and, further, that the interior surface of the retort acquired a coating of silver, so that the iron and the liquid soon ceased to be in contact. This point has not been sufficiently studied; but the fact has been placed beyond doubt that the operation succeeds very well in iron vessels, and accordingly, in many refining establishments, no other are employed.

It cannot fail to be observed that, assuming the proportions above given, the quantity of sulphuric acid is much greater than would be strictly necessary to convert the silver and copper into sulphates. Supposing the alloy to be as poor as possible in gold, theory would indicate the following quantities of acid as being sufficient for this purpose:—

	Parts.		Parts.	
Copper	50	would require	155	sulphuric acid.
Silver	949	,, ,,	861	,, ,,
Gold	1	,, ,,	0	,, ,,
Alloy	1000	,, ,,	1016	,, ,,

But as the amount of sulphuric acid employed is actually 3500 to 1000 of alloy, there is an excess of about 2500 of acid, intended to hold the sulphates, and especially the sulphate of copper, in solution.

When the silver and copper are completely dissolved, the retorts are withdrawn from the fire, and the solution is left to cool, that the gold may settle to the bottom. The liquid is then decanted; the gold, which remains in the vessel, is carefully washed, and the waters employed in this operation are added to the sulphate solution. Lastly, the purified gold is melted, and after being cast into ingots, is ready for commerce.

The acid liquor, containing the sulphates, is poured into a leaden boiler, containing water and copper shavings. Heat is applied, and the sulphate of silver is soon completely decomposed. The precipitated silver is collected, and submitted to repeated washings, always adding the water to the boiler, for use in the next operation. Lastly, the silver is dried in a small iron pan, and is then melted in a crucible, to be cast into ingots.

The acid solution, which now contains only sulphate of copper, is evaporated in lead boilers till it is fit to crystallize. It is then put into the crystallizing pans, and the mother waters are further evaporated, to obtain more crystals. This process is continued till the liquid becomes very concentrated, and consists almost entirely of sulphuric acid. In this state it is termed *black acid*, on account of its color, which is due, in great part, to organic matters, dust, and other impurities, which fall in it during the evaporation in the crystallizing pans. The black acids, purified by concentration, may either be employed to repeat the same operation, or turned to useful account in different manufacturing processes, which do not require that the sulphuric acid should be pure and highly concentrated.

2. *By Nitric Acid.*—The operation of parting is performed with nitric acid in much the same way; but all the details of the process with this acid will be minutely explained in connection with the subject of assaying, for which it is uniformly used.

3. *By fusion with Sulphur.*—Another method of separating the gold from the silver, which is sometimes practised with alloys containing but very little gold, is by fusing the granulated alloy with three-tenths of its weight of sulphur; this combines with the silver, and forms a liquid sulphide, in which the finely-divided gold remains suspended. A small quantity of litharge is then added, which gives rise to the formation of sulphurous acid and sulphide of lead, and again separates a portion of the silver, which then combines with the gold, forming an alloy richer in the latter metal. This alloy, by its greater gravity, sinks to the bottom of the crucible, and, after cooling, is separated by the hammer from the superincumbent mixture of sulphide of silver and lead. When this mixture, which is termed *plachmal*, is fused with a small quantity of litharge, it yields silver, which for the most part [illegible] contains a little gold. The richer alloy which subsides to the bottom of the crucible, is treated repeatedly with sulphur in the same manner, till the proportion of gold is raised to one-fourth, after which the final separation of the silver is usually effected with nitric or sulphuric acid. It will be observed that this process is similar in principle to the method already described for concentrating auriferous pyrites.

4. *By fusion with Sulphide of Antimony.*—In this case, the alloy is mixed with two parts by weight of sulphide of antimony, and fused, with constant stirring, in a crucible, which should be previously glazed with borax. By this means sulphide of silver is formed, and the gold combines with the antimony, forming a lower stratum of alloy, which is afterwards separated from antimony by simple ignition in the air, or by fusion with nitre. If the amount of silver in the original alloy exceeds one-third, a proportional quantity of sulphur must be added in the crucible. The sulphide of silver forming the upper stratum retains a small portion of gold, to separate which it is again twice fused with sulphide of antimony, and this is again removed by ignition or fusion with nitre. The same operations are repeated on the whole amount of antimonide of gold thus obtained, and the antimony is finally removed either by fusing the antimonide alone, while air is blown upon it, or by fusion with three times its weight of nitre. Sometimes it is melted into a mass by heating it with three-fourths of its weight of borax, one-fourth of nitre, and one-fourth of glass.

5. *By Cementation.*—Another method, which is practised in America, consists in arranging the granulated alloy in alternate layers, with a mixture of two parts of brick-dust and one part of chloride of sodium in *porous crucibles*, which are exposed to a low red heat in a wood fire for a period varying from twenty-four to thirty-six hours. The aqueous vapor from the wood permeates the crucibles, and acts upon the salt in such a manner as to separate hydrochloric acid, which then forms chloride of silver with evolution of hydrogen. The chloride of silver, together with the chloride of sodium, sinks into the brick-dust, and the gold obtained after washing, contains not more than from one-tenth to one-eleventh of silver.

In this case, without the brick-dust, the conversion of the silver into chloride would be only superficial, because the chloride first formed would protect the inner portions of the alloy from the action of the hydrochloric acid. But when the alloy is enveloped in brick-dust, the chloride of sodium is partly decomposed by the silica, yielding silicate of soda and hydrochloric acid; the latter converts the silver into chloride, which then fuses with the rest of the chloride of sodium, and this, sinking into the brick-dust, leaves a new surface of alloy exposed to the action of the hydrochloric acid.

The reader will observe that the three methods last mentioned are all more or less imperfect in their results, and that for the complete separation of the silver, recourse must always be had to the action of sulphuric or nitric acid.

ALLOYS OF GOLD.—STANDARD GOLD.—By the preceding series of mechanical, metallurgical, and chemical operations, gold may be brought to a state of nearly absolute purity; but in this state it is too soft to be employed with advantage in the arts, or for the purposes of the coinage. Gold is therefore almost always alloyed with a greater or less proportion of some other metal, except when it is found in the shape of the finest gold leaf, which requires for its proper manufacture the highest possible purity, because, although it readily forms alloys with most of the other metals, its malleability is greatly impaired by their presence in even a very small proportion. With some metals this effect is very remarkable; even one two-thousandth part of antimony, bismuth, tin, or lead, will render the gold quite brittle. At the same time, as a natural consequence, its hardness and sonorousness are increased.

The only alloys of gold of any importance in the arts are those formed with silver and copper, which tend to increase its hardness and durability, and are used also by jewellers to give the gold different tints, according to the proportions employed. It singularly happens that these are the metals with which it is chiefly combined in the native state, although it is likewise found associated with iron, platinum, tellurium, and other metals.

Gold may be alloyed with silver in almost all proportions, and, by its combination with this metal, it becomes not only harder and more sonorous, but also more fusible. As the proportion of silver increases, the color quickly passes through pale greenish-yellow into white. The malleability of gold is less diminished by silver than by any other metal. The maximum of hardness is found in the alloy containing two parts of gold to one of silver. The *green gold* of the jewellers contains twenty-five per cent. of silver.

The most useful alloy of gold is that which is formed with copper, and this is the alloy which is used for coinage. The addition of copper renders gold redder, harder, and more fusible. The maximum of hardness is exhibited by an alloy of seven parts gold and one of copper. An alloy containing twenty-two parts of gold and one of copper has a density of 17·157. English standard gold contains 8·33 per cent. of copper, or one part of this metal to eleven parts of gold. In France, the standard gold contains ten per cent of copper. Gold contracts in the act of solidifying from a state of fusion, and cannot, in consequence, be made to receive sharp impressions by casting it in moulds. Coins are, therefore, stamped with a die, and plate is either stamped or embossed, and afterwards chased and carved, if necessary, by cutting tools.

Valuation of Gold Alloys.—In this country the standard of the alloys of gold is calculated in fractions of unity expressed in carats. Perfectly pure gold is taken as unity, and this is assumed to consist of twenty-four fractional parts termed *carats*, each of which is divided into four imaginary grains, and these are again subdivided into quarters and eighths. The carat is, therefore, ultimately divided into thirty-two thirty-seconds; so that unity, or absolute fineness, represented by twenty-four of these carats, may be considered as made up of 24 × 32 = 768 thirty-seconds. On this system, an alloy of gold, according to its composition, is spoken of as being so many carats fine, or so many carats and thirty-seconds of a carat. It has been stated above that the standard alloy of the English gold coinage contains eleven parts of gold to one of copper, or, in other words, twenty-two parts of gold to two of copper; it is, therefore, said to be twenty-two carats fine. If the alloy contained twenty-three parts by weight in the twenty-four, it would be twenty-three carats fine, or one carat *better than standard.* If, on the other hand, it contained only twenty-one carats, it would be one carat *worse than standard;* if it contained 18·5 of pure gold, it would be said to be eighteen carats, and sixteen thirty-seconds. The report of the assayer is always given in relation to standard. Fine or pure gold would be twenty-four carats fine, that is, there would be no alloy.

In calculation it is easier to use decimal fractions than the clumsy empirical system of counting by carats; and in estimating silver the decimal method has lately been introduced into the mint of this country by Sir John Herschel. In France the same method is generally extended to gold. Upon the decimal system, fine gold or silver is termed 1000·0, and the report upon any sample of alloy simply indicates the number of parts of pure gold or silver in 1000 which the sample contains. Unfortunately the English standard does not admit of expressing the amount of copper in a terminable decimal, the nearest convenient fraction being 90·91 of copper in 1000 of alloy. In France, the standard is conveniently expressed by 900 of gold to 100 of copper. This decimal standard admits of the ready comparison of gold alloys with other chemical compounds, because in analytical investigations the results are always sought with reference to the percentage or centesimal composition of the subject under examination; but, under the system existing in this country and on many parts of the Continent, it is often necessary to convert the per-centage into the corresponding value expressed in carats. The following table, which expresses the relation subsisting between a series of decimal fractions of unity and the carats and thirty-two thirty-seconds respectively, will be found convenient for immediately effecting the conversion:—

Thirty-seconds of the carat.	Decimal.	Carats.	Decimal.
1	0·001302	1	0·041667
2	0·002604	2	0·083334
3	0·003906	3	0·125001
4	0·005208	4	0·166667
5	0·006510	5	0·208333
6	0·007912	6	0·250000
7	0·009215	7	0·291666
8	0·010415	8	0·333333
9	0·011718	9	0·374999
10	0·013021	10	0·416667
11	0·014323	11	0·458630
12	0·015625	12	0·500000
13	0·016927	13	0·541667
14	0·018230	14	0·583333
15	0·019531	15	0·624555
16	0·020833	16	0·666667
17	0·022135	17	0·707333
18	0·023436	18	0·750000
19	0·024740	19	0·791666
20	0·026042	20	0·833333
21	0·027343	21	0·874999
22	0·028646	22	0·916666

Thirty-seconds of the carat.	Decimal.	Carats.	Decimal.
23	0·029948	23	0·958333
24	0·031250	24	1·000000
25	0·032552	—	——
26	0·033854	—	——
27	0·035156	—	——
28	0·036460	—	——
29	0·037760	—	——
30	0·039062	—	——
31	0·040364	—	——
32	0·041667	—	——

Jewellers' Gold.—The jeweller receives his gold in the form of ingots, which approach to absolute purity, or twenty-four carats fine. He begins his operations by alloying it with copper or silver, or both, in certain calculated proportions, either to reduce it to the legal standard, or to give it the particular color required. The following are the three standards fixed by the latest statutes enacted in France on the subject:—1. *High standard gold*, consisting of nine hundred and twenty parts of pure gold in one thousand of alloy, which is equivalent to twenty-two carats, one thirty-second and one-half. This is the alloy usually employed by the French jewellers, and is nearly identical with the standard gold of the English coinage. 2. *French standard gold*, consisting of eight hundred and forty parts of gold in one thousand of alloy, or twenty carats, five thirty-seconds, and one-half. Sometimes it is reduced to only twenty carats. 3. *Common gold* is seven hundred and fifty parts in one thousand, or eighteen carats. The licence or *tolerance* allowed is three parts in a thousand.

In order that the gold may be easily worked, the alloy must be perfectly homogeneous, and the jeweller accordingly brings it to this state by repeated fusions. If the alloy has been badly made, and still exhibits a grainy appearance, with a liability to crack under the action of the hammer or between the laminating rollers, it must be again introduced into the crucible, and thoroughly fused with a mixture of borax and saltpetre.

In the *Dictionnaire des Arts et Manufactures*, the colors most commonly required in articles of jewellery, are stated to be composed as follows:—

Colors.	Composition.
Yellow gold,	Pure or fine gold, 1000.
Red gold,	Fine gold, 750; rose copper, 250.
Green gold,	Fine gold, 750; silver, 250.
Dead-leaf gold,	Fine gold, 700; silver, 300.
Water-green gold,	Fine gold, 600; silver, 400.
White gold,	An alloy of gold and silver in which the latter predominates.
Blue gold,	Fine gold, 750; iron 250.

The last-mentioned alloy is somewhat difficult to prepare. It is obtained by introducing thick iron wire among the melted gold, and withdrawing the crucible from the fire as soon as the alloy is formed. When poured out and cooled, it should have no appearance of porosity. It is then forged, and formed into sheets or wires of different thicknesses.

Various shades of color are likewise given by the jeweller to articles or ornaments of gold, by the finishing process, which consists in exposing them to certain chemical agents, to dissolve out a portion of the copper or silver from the surface, without attacking the gold. By this means the surface of the article is made to appear like pure gold, which it really is, while below the surface the quantity of copper or silver may be considerable. The liquor usually employed by the goldsmiths and jewellers for this purpose is a mixture of two parts of nitrate of soda, one part of chloride of sodium, and one of Roman alum, in three or four parts of water. The trinkets or other articles are kept in this solution, at the boiling point, from fifteen to twenty-five minutes, according to the shade required. They are then taken out, washed in water, and after burnishing with blood-stone, the operation is finished. The pickle, or sauce, as the liquor is termed, dissolves not only the copper or silver alloy on the surface, but likewise a certain quantity of the gold itself, and the articles lose, on the whole, about one-sixteenth of their weight by the operation. To recover the gold, the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure protosulphate of iron is poured into it. The precipitated gold is washed upon a filter, dried, and purified by fusing in a crucible, along with a mixture of equal parts of nitrate and biborate of soda. The other metals can likewise be recovered by very simple methods.

Gold-Beating.—The art of beating gold into thin leaves seems to have been known from a very remote period. The fact that the Hebrews were acquainted with it has been already stated,—and from the circumstance that, on the coffins of the Theban mummies, specimens of leaf-gilding are met with, in which the gold is so thin as to resemble modern gilding, it may be inferred that the Egyptians had carried the art to a high degree of perfection. This art is distinctly referred to by Homer, and was practised extensively by the later Greeks, even to decorate the external sculpture of their temples and statues. Pliny states that after the destruction of Carthage the Romans began to gild the ceilings of their temples and palaces, and that luxury advanced on them so rapidly that, in a little time, even private and comparatively poor persons gilded the walls, vaults, and other parts of their dwellings. Horace's remark, that *neither ivory nor gilded arch figured in his house*, is familiar to the classical student. Pliny further states, that one ounce of gold was extended to 750 leaves, each four fingers square. Lucretius compared the Roman gold-leaf to a spider's web, and Martial described it as little other than a vapor; yet, according to Pliny's account, it must have been three times the thickness of the ordinary leaf-gold of the present time.

Experiments have been made to ascertain to what degree of thinness gold and silver could be reduced: it was found that one grain of gold was spread to the extent of seventy-five square inches, and the same weight of silver to the still more extraordinary dimensions of ninety-eight square inches. Taking one cubic inch of gold at four thousand nine hundred grains, it will be found that the gold was the three hundred and sixty-seven thousand five hundredth part of an inch in thickness, or about one thousand two hundred times thinner than ordinary printing paper. Thus, if three hundred and sixty-seven thousand leaves of gold were placed on one another they would constitute a pile only an inch high, while the same number of leaves of paper would form a pile half the height of the Monument of London. The same *weight* of silver, though extended over a much larger surface, was thickest, owing to the difference in its specific gravity. In practice, the gold leaf is never extended beyond the one-two hundred and ninety thousandth part of an inch in thickness.

The late Dr. URE erroneously states, that the gold used in gold-beating ought to be of the finest standard. Alloy, he adds, hardens gold, and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold would expose himself to much greater loss in the operation than he could derive of profit from the alloy. From this statement it might be inferred that nothing but fine or perfectly pure gold is used by the gold-beater, whereas, in point of fact, it is variously alloyed, according to the color required. Indeed, it is not uncommonly supposed, among the workmen employed in the business, that fine gold is incapable of being reduced to thin leaves; but this also is an error. It is simply objectionable for commercial purposes, on account of its greater cost, and also on account of the adhesion which takes place when one part of a leaf of fine gold touches another, thus causing a waste of labour, by the leaves being spoiled. For work, however, which is to be exposed to the weather, fine gold is the best, being more durable, and not liable to tarnish or change color.

A London gold-beater, Mr. E. S. MARSHALL, exhibited specimens of gold-leaf at the Great Exhibition of 1851, for which the prize medal was awarded to him. The specimens were twelve in number, and embraced a regular gradation in color from red to nearly white—namely, red, pale red, extra deep, deep, orange, lemon, deep pale, pale, pale pale, deep party, party, and fine gold. The deeper colors were alloyed with from twelve to sixteen grains of copper per ounce, but no silver, since any admixture of this metal with so large a quantity of copper would considerably impair the malleability of the alloy; the medium colors contained from twelve to twenty grains of silver, with from six to eight grains of copper, to the ounce; and, lastly, the paler leaves contained from two to not less than twenty pennyweights of silver to the ounce, but no copper, for the same reason that silver was omitted in the red or deep-colored golds.

The process of gold-beating is purely a mechanical operation, but involving as it does one of the most important applications of this precious metal, it will be necessary to give a short account of it. The first operation is the *casting of the metal into ingots*. For this purpose the gold, either pure or alloyed, according to the color desired, is melted in a crucible at a higher temperature than is simply necessary to fuse it, by which its malleability is improved. It is then poured into moulds previously heated and greased on the inside, and cast into flat oblong ingots, each about three-fourths of an inch wide, and weighing two ounces. The ingots, when taken from the moulds, are annealed in hot ashes, which cleanse them from grease and increase the malleability of the gold. When the ingot is cold, the French gold-beaters hammer it out to the thickness of one-sixth of an inch, and expose it at the same time to repeated annealings; but this operation, termed the *forging*, is omitted by the English gold-beaters. The next process is the *lamination*, which consists in repeatedly passing the ingot between two rollers of polished steel, gradually brought closer together, until it is formed into a riband of one and a half inch in width, and ten feet in length, to the ounce. By this means the ingot is spread out to a surface of nine hundred and sixty square inches of the thickness of rather more than one-eight-hundredth of an inch. The next operation is the *beating*, for which purpose the riband of gold, after being annealed or softened in the fire, is carefully divided with compasses and cut up into pieces of the size of a square inch, each weighing about six grains; about one hundred and sixty of these are placed by means of wooden pliers between the leaves of a *cutch*, which formerly consisted of a packet of fine calf-skin vellum, but now it is usual to employ a tough paper manufactured in France. A case of strong parchment, open at both ends, is drawn over the cutch, and this is enclosed in a second similar case at right angles to the first, so as to cover the edges which the first had left exposed. The cutch is then beaten with a seventeen-pound hammer, upon a smooth block of black marble, supported on a strong bench, and surrounded on three sides by a wooden ledge, while the front is left open, and has a leathern apron attached to it, to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is wielded by the workman with one hand, while with the other he occasionally turns the packet over, to distribute the force equally. The elasticity of the packet causes the hammer to rebound, and lightens the labor of the operator. At intervals the packet is taken up, and bent or rolled between the hands, to overcome any slight adhesion between the leaves and the interposed paper or vellum; or it is taken to pieces to examine the state of the gold, and to shift the central leaves to the outside, and *vice versâ*.

When the gold plates of one inch square are thus spread out into four-inch squares, or to nearly the size of the leaves of the cutch, which generally requires about twenty minutes' beating, the packet is opened, and each leaf of gold is taken out, and cut with a knife into four equal squares, thus increasing the one hundred and fifty pieces to six hundred of nearly the same size as at first. These are put between the leaves of another tool, called a *shoder*, made of *gold-beater's skin*. This substance is the cæcum of the ox, which is first doubled, then prepared with solutions of alum, isinglass, white of egg, *et cetera*, and after being beaten between folds of paper to expel the grease, is finally pressed and dried. The shoder is enclosed in parchment and beaten as before, but with a smaller hammer, about nine or ten pounds weight, till the squares of gold are again extended to nearly the size of the skins. The shoder requires about two hours' beating for this purpose. During this period, the packet must be often folded, to render the gold as loose as possible between the membranes. As all the leaves do not spread quite equally, the shoder is beaten upon after the more expanded leaves have reached the edges, the effect of which is, that these come out of the edges in the shape of dust, and this allows time for the smaller leaves to reach the full size of the shoder.

The packet is now opened, and the leaves of gold, being spread on a cushion, are again subdivided into fours, by means of two pieces of cane cut to very sharp edges, and fixed down cross-wise on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions, and is preferable to a steel knife, to which the gold, in its now attenuated state, would be liable to adhere. The two thousand four hundred squares thus formed are separated into three parcels of eight hundred each, and the squares of each parcel are placed in another shoder or mould composed of gold-beater's skin, enclosed in the parchment cases, and beaten as before. This is the last and most difficult stage of the process. The mould must be made of the finest skins, about five inches square; and on the fineness of the skin, and the judgment and dexterity of the workman, the perfection and thinness of the leaf of gold depend. A seven-pound hammer is now employed, and after two hours' beating, the gold is reduced to the one hundred and fifty thousandth of an inch in thickness, and begins to transmit the rays of light. When the gold is quite pure, or but slightly alloyed, it transmits the green rays, but in gold highly alloyed with silver, the pale violet rays are transmitted. After being hammered another two hours, the leaves acquire the tenuity of ordinary leaf-gold, and average from three to three and a half inches square. The three beatings and two quarterings expand the gold to an area about one hundred and ninety times greater than it had in the form of a riband, and one hundred square feet of it weigh only an ounce. It is true that an ounce might be hammered to cover an area of one hundred and sixty feet; but in this case the gold would be too much attenuated for common use, and the extra labor and care required would not be compensated by any corresponding advantage. After the last beating, the leaves are lifted one by one with a delicate pair of long pincers, made of white wood, and are spread out on a leathern cushion by blowing them flat with the mouth. Broken or blemished leaves are rejected; the good ones have the ragged edges cut off with a square frame of sharp cane, which reduces them all to a uniform size, and are then placed in a book, the leaves of which have been rubbed with red ochre, to prevent the gold from adhering. Each book is capable of holding twenty-five leaves, and in this form the gold-leaf is sold for gilding picture-frames and books, and for the various ornamental purposes to which it is applied in the arts.

In this country the art of gold-beating was long confined to London, where it has been carried to higher perfection than in any other part of the world; but, of late years, efforts have been made on the Continent, with the aid of English gold-beaters' skin, to emulate the beauty and fineness of the English product; and the art is now practised successfully in different large cities in England, as well as in Scotland and Ireland. Latterly, machinery has been applied to supersede the arduous manual labor of gold-beating with the hammer, and machines for this purpose were sent to the Great Exhibition from France and the United States. There was also exhibited a specimen of leaf-gold, manufactured in London by means of steam machinery; and there is little doubt that the article, so manufactured, will ultimately supersede the product of manual labor.

GILDING.—This is the art of applying a superficial covering of gold to articles of wood, metal, *et cetera*, chiefly for the purpose of ornament, but sometimes also for utility, as when it is essential that the article should be preserved from tarnishing. Gilding is practised by various methods, the principal of which may be classified under the following heads, namely: 1. Mechanical gilding with gold-leaf for wood, leather, *et cetera*; 2. Chemical gilding, properly so called, which is practised on metallic substances, and includes wash-gilding, or gilding by amalgamation; gilding by immersion, and various other processes; 3. Electro-gilding, commonly known as the electrotype.

1. *Mechanical Gilding*, or gilding on wood with gold-leaf, is of two kinds, distinguished as burnish-gilding and oil-gilding.

In *burnish-gilding*, the process may be exemplified as applied to a picture-frame. In this case the gilder receives from the joiner a bevelled moulding twelve feet in length, which he prepares for gilding by a number of preliminary coatings of size, mixed with different substances. He first gives it a priming of hot size and whiting, this mixture being laid on in a somewhat fluid state, and therefore termed *thin-white*. It is prepared by melting the size in an earthen pipkin, and stirring in the whiting in fine powder by small portions at a time. When this first coating is dry the surface is examined, and all holes and irregularities are filled up with a mixture of whiting and size, made of the consistence of putty, but containing no oil. The moulding then receives four or five layers of a mixture similar to the first, but of greater consistence, and therefore termed *thick-white*, allowing time between each layer for the work to dry. While each of these last coatings is still wet, the fine work of the moulding is kept open by means of chisels, gouges, and other tools for the purpose. Sometimes two thick-whites are laid on successively, without allowing the first to dry, and are then worked into the shape of the moulding by hard stones of the required form. The whiting is now from one-sixteenth to one-twelfth of an inch in thickness, and is trimmed to remove the unevenness at the edges, after which the entire surface of the moulding is smoothed with pumice-stone, formed to fit exactly into the various parts, which are slightly wetted to promote the smoothing effect. The final polish of the whiting is given with glass-paper.

The moulding is now ready to receive the gold-size, which consists of pipe-clay, red chalk, black lead, suet, and bullock's blood. Of this mixture, which is sold to the gilder in a tenacious mass, rather softer than butter, a portion is taken and melted with common clear thin size; and while still slightly warm, is laid on with a brush, and with great nicety of hand.

The next operation is the gilding, for which several tools are required,—a leathern cushion to receive the gold-leaf, a knife for cutting it into different sizes, and a little instrument, termed a *tip*, for laying the leaf on the moulding. This last instrument consists of two pieces of card glued together, with the ends of a row of camel's hairs fastened between them, and projecting from one inch to one inch and a half. The gilder having moistened with water a few inches of the moulding about to be gilded, and having cut a leaf into stripes suited to the width of the part on which it is to be laid, touches one of these stripes with the tip, to the hairs of which it slightly adheres, and transfers it to the moistened part of the moulding. When the whole of the moulding has been thus covered, it is set aside to dry.

The next process is the burnishing, which is performed by rubbing briskly over the gold a piece of flint or agate. This greatly increases its brilliancy, and does not injure the gold-leaf on account of the foundation of gold-size and whiting which yields under the hand. The parts which are to be in *dead* gold or *matt*, are left unburnished, but over these parts a very thin, clear size is passed, and, when dry, the gold is carefully wiped with soft cotton wool. The work is completed by wetting the matt parts with a pencil dipped in clear finishing size. The moulding is then passed into the hands of the frame-maker, who cuts it up and forms it into a frame of the required size.

When the frame or other article to be gilt is somewhat richly ornamented, *oil-gilding* is used. In this case the moulding is first whitened as before, but is then made up to the required shape, and decorated with composition ornaments before the application of any further primings. In this state the gilder receives the frame, and his first operation is to wash it, in order to free it from oil or other impurities. He then gives it two or three coatings of thin-white, mixed with a little soft clay, and several additional coatings are given to the parts intended to be burnished. Two or three coats of a moderately strong size called *clear-cole* are now spread over the whole, after which the *oil gold-size*, consisting of a mixture of boiled linseed-oil and ochre, is laid on smoothly with a brush. After six or eight hours, when the oil-size has been partially dried, the gold-leaf is applied as before, except that in this case no water is used, the oil serving the same purpose. For deep ornaments, the gold is pressed in with cotton-wool, and in this case the gilding has to be repeated to remove the irregular fractures known by the gilders as *spiders' legs*. The work, which has still a ragged appearance, is now carefully gone over and smoothed with a brush—superfluous gold being removed from some parts and worked into others. This operation is termed *skewing*. The parts to be burnished are then treated as before, and finally the frame, after being dusted, is sized with clear size, and yellowed on the outside.

Another application of gold-leaf is to book-gilding. When the book is bound in leather, the back and sides to be gilt are first covered with a coating of isinglass, or white of egg, dissolved in a large proportion of water, and termed *glaire*. This is allowed to dry, and when the gold-leaf is about to be laid on, a woollen rag, slightly moistened with hog's lard or sweet oil, but so as to feel almost dry to the touch, is rubbed over the leather. This causes the adherence of the gold-leaf, which is laid on over the whole space intended to be covered by the figure, and is then imprinted with a hot brass block, cut to the required design or letters. For this purpose a blocking-press is employed, and in the upper bed is a cavity containing a row of gas jets for keeping the block at the proper temperature. After the block has been brought down by means of a lever, the gold is readily brushed off from the parts which have not received the impression. Books bound in cloth are treated in the same manner, except that they do not receive the preliminary coating of glaire, the place of which is supplied by a portion of the glue under the cloth being raised by the heated block. The edges of the leaves of books are gilded in the bookbinder's press by applying a solution of isinglass or white of egg, moistened with oil, and then laying on the gold-leaf, which is firmly pressed down and burnished with agate, bloodstone, or polished steel. Instead of isinglass or ovalbumen, the serum of bullock's blood is often employed.

2. *Chemical Gilding.*—When metallic surfaces are to be gilded, the gold is applied either in the state of an amalgam, which is termed *wash-gilding*, or is deposited by chemical affinity from its solution.

Water or *Wash gilding* consists in applying evenly an amalgam of gold to the metallic surface to be gilt, and then dissipating the mercury by heat so as to leave on the surface a film of pure gold. Ordinary brass answers very well for gilding on, but the alloy which is now generally preferred is a mixture of copper, nickel, and zinc, which may be so proportioned as nearly to resemble gold in color. To form the amalgam, a small quantity of gold, reduced to grains or thin plates, is heated in a crucible till it becomes faintly red, and then thrown into mercury, also previously heated till it has begun to emit visible vapor. The proportion of mercury to gold is generally as six or eight to one. The mercury is then stirred with an iron rod till all the gold is dissolved. The crucible is now removed from the fire, and the amalgam, when cold, is squeezed in a bag of chamois leather, for the purpose of straining off the superfluous mercury. The true amalgam which remains consists of about thirty-three of gold and fifty-seven of mercury in a hundred parts; it is a yellowish silvery mass, of the consistence of butter.

Before applying the amalgam to the metallic surface, the latter is rubbed over with a solution, formed by dissolving a hundred parts of mercury in a hundred and ten parts, by weight, of nitric acid, of specific gravity 1·33, and diluted with about twenty-five times its weight of distilled water. This solution not only cleanses the metal from any rust or tarnish, but in consequence of the stronger affinity of the copper alloy for nitric acid than the mercury has, the latter is precipitated upon its surface in the samo manner as a piece of polished iron precipitates copper from a solution of the sulphate of that metal. The amalgam is now spread evenly over the alloy to be gilt by means of a brush, and readily adheres to the metallic surface in consequence of the thin film of mercury already deposited upon it. Sometimes the metal is previously cleaned with sulphuric acid, and the nitrate solution and amalgam aro then applied simultaneously For this purpose a gilder's scratch-brush, made with fine brass-wire, is first dipped into the nitrate of mercury solution, and is then drawn over a lump of amalgam, placed on the sloping side of an earthen vessel, after which the brush is applied to the surface of the alloy. This process is repeated till the whole is coated with its just proportion of gold. The article is then bathed in water, dried, and exposed to a fire of glowing charcoal to expel the mercury. The heat applied must be just sufficient for this purpose, and the article must be turned about to expose it equally on all sides. From time to time it is withdrawn from the fire, and while the operator holds it in his left hand, protected by a stuffed glove, he spreads the amalgam equally with his right hand by means of a long-haired brush. The piece is then returned to the fire, and the same operations are repeated till the mercury has entirely volatilized. This is known by the surface becoming of a dull yellow color, and by the hissing sound of a drop of water let fall upon it.

The surface, now coated with a film of gold, is still deficient in polish and lustre. To communicate these qualities, it is washed and well rubbed with a scratch-brush in water acidulated with vinegar. It is then covered with a composition called *gilding wax*, which is simply a mixture of bees' wax with some of the following substances, namely, red ochre, verdigris, copper scales, alum, vitriol, and borax. Coated with this composition, it is again exposed to the fire until the wax is burnt off. By this means the gilding is found to be heightened in color, probably in consequence of the complete dissipation of some of the mercury remaining after the former operations. If the article is wrought or chased, the parts intended to be burnished are now rubbed with a steel burnisher, dipped in acidulated water, till a fine metallic lustre is produced. Formerly hæmatite or bloodstone was almost exclusively used for this purpose, but is now generally abandoned for the use of the steel burnisher, which is case-hardened and then carefully polished. The parts intended to be deadened are coated with a mixture of sea-salt, nitre, and alum, fused in the water of crystallization of the last-mentioned salt; the article is then heated till the saline crust with which it is covered enters into fusion, and becomes homogeneous, after which it is withdrawn and suddenly plunged into cold water, which entirely detaches the crust. Lastly, the piece is passed through weak nitric acid, washed in pure water, and dried.

Gilding by immersion is another method by which copper trinkets and stamped articles can be coated with a thin film of gold. This method, which dispenses with the dangerous use of mercury, so detrimental to the health of the workmen, was patented by Mr. ELKINGTON, of Birmingham, in 1836, and has been very extensively practised, more especially in France. In this process the copper or other metallic articles to be gilt, are, after being well cleansed, immersed in a boiling-hot solution of terchloride of gold mixed with a solution of bicarbonate of potassa. The adhesion of the gold to the inferior metal takes place in consequence of a portion of the copper becoming dissolved by the action of the potassa, and the deposition of an equivalent of gold upon the copper article in its stead. The details and rationale of the process are thus described by Dr. MILLER of London:—The gilding-bath is prepared by dissolving one part of fine gold in aqua regia, and expelling the excess of acid by evaporation. The chloride is dissolved in a small quantity of water. To this solution thirty parts of bicarbonate of potassa are gradually added. This liquid is then mixed with a solution of thirty parts more of the bicarbonate, dissolved in two hundred parts of water, and the liquid is boiled for two hours. During this operation the bicarbonate of potassa is converted into the sesquicarbonate, and the yellow liquid passes into green; after this, the solution is ready for use. The trinkets having been annealed, are cleansed from adhering oxide by a momentary immersion in a mixture of equal parts of sulphuric and nitric acids; to which, when the gold is intended to have a *dead* appearance, a little chloride of sodium is added. The articles are washed in water, and then plunged into the gilding liquid, where they are left for about half a minute, after which they are washed in water and dried in hot sawdust. This bath may be also employed for gilding on German silver, platinum, or silver, by immersing the objects composed of these metals in the liquid, in contact with wires of copper or of zinc. During this process of gilding, a remarkable reaction occurs—the gold imparts a portion of its chlorine to the excess of potassa contained in the bath, forming chlorate of potassa; protochloride of gold is formed, and is decomposed by the copper, —chloride of copper being produced, whilst metallic gold is deposited upon the surface of the trinkets:—

$$6\ Au\ Cl_3 + 6\ KO + 12\ Cu = 12\ Cu\ Cl + 5\ K\ Cl + KO,\ Cl\ O_5 + 6\ Au.$$

During this operation a black powder is precipitated, which contains hydrated carbonate of copper, mixed with a small proportion of the purple of Cassius derived from the action of the gilding solution upon the tin contained in the solder of the trinkets. The compound termed the purple of Cassius will be described afterwards.

Gilding on iron and steel cannot be well performed directly by the method of amalgamation, as it is difficult to prevent the oxidation of the metal during the volatilization of the mercury, and the temper of sword-blades, daggers, and other such instruments, to which the gilding is usually applied, is liable to be injured in the process. It may be effected, indeed, by previously applying to the polished surface the solution of nitrate of mercury already described, and known as *quicksilver water;* the acid so applied unites with a portion of the iron or steel, and deposits in its place a thin coating of mercury, which combines with the gold amalgam when brushed on. By this method, however, a bright and durable gilding cannot be obtained.

Another not very successful method of gilding on polished iron and steel, is by means of an ethereal solution of terchloride of gold. For this purpose the gold is first dissolved in aqua regia, and about twice the quantity of ether is then cautiously added in a large vessel. The liquids are agitated and allowed to rest, when the ether will separate, and float on the surface of the acid. The whole mixture is now poured into a funnel terminating in a small aperture, and again allowed to settle and separate, after which the acid is run off from below. The ether which remains has taken up all the gold, and before applying it to the iron or steel, the metal is polished with the finest emery and spirit of wine. The ether is then laid on with a small brush, and as it evaporates it deposits the gold, which can now be heated and polished. This gilding, however, is neither very rich nor durable, in consequence of the affinity between gold and iron being feeble compared to that between gold and copper or silver.

But polished iron and steel, as well as copper, may be effectively gilded with gold-leaf by the application of heat. For this purpose, the metals are heated till the iron assumes a bluish tint, and till the copper has acquired a like temperature. The first coat of leaf-gold is then applied, being pressed gently down with a burnisher, and then exposed to a moderate heat. Several leaves, either single or double, are thus successively applied, and the last is burnished down cold. This is the method usually practised in gilding iron or steel.

Gilding on silver is performed by means of the ashes of a linen rag, which has been dipped in a solution of gold and copper in aqua regia. For this purpose, sixty grains of fine gold and twelve of rose copper are dissolved in two ounces of aqua regia. With this solution a quantity of linen rags sufficient to absorb all the liquid is soaked. The rags are then dried and burned, and the ashes contain the gold in powder. A moistened cork or piece of leather is dipped into this powder, and after the article to be gilt has been well annealed and polished, the ashes are rubbed over it with the cork till the surface appears sufficiently gilded. Large articles are finally burnished with bloodstone, and small ones with steel burnishers, along with soap-water.

Gilding on glass or porcelain is effected with pulverulent gold, or gold precipitated from its chloride solution by means of sulphate of iron. In this state the gold is mixed with one-twelfth of its weight of oxide of bismuth, together with a small quantity of borax and gum-water, and is applied to the parts to be gilt with a camel's hair pencil. The article is then heated in a muffle, and when removed the gold appears of a dingy color, but the lustre is brought out by burnishing with agate or bloodstone. Lastly, it is cleaned with vinegar or white-lead.

Vessels which are not often used, and are not liable to wear, may easily be gilt in a less durable manner, by fixing gold-leaf upon them with copal varnish.

3. *Electro-Gilding.*—This process, which has now almost entirely superseded the method by amalgamation, is applicable not only to metals, but to wood, plaster, or any other substance capable of receiving a coating of plumbago, or of PARKES' patent preparation of phosphorus. Full details of this beautiful process have been given in the article ELECTRO-METALLURGY, to which the reader is referred.

ARTIFICIAL GOLD.—Under the name of Californian gold, and other sounding titles, are sometimes sold alloys which do not contain one grain of the precious metal, but merely resemble it in color and lustre so long as they remain untarnished. It is stated that a good imitation has lately been formed by Messrs. MOURIER and VALLENT, of Paris. The materials and proportions used by them are—pure copper, 100 parts by weight; zinc, 17; magnesia, 6; sal ammoniac, 3·60; quicklime, 1·80; tartar, 9. The copper is melted in a crucible, in a suitable furnace; the magnesia, sal ammoniac, lime, and tartar, are then added, separately and by degrees, in the form of powder; the whole is stirred for about thirty minutes to thoroughly mix the ingredients, and the zinc is then thrown on the surface, having first been ground into very small grains; the stirring is continued until the fusion is complete. The crucible is now covered, and the fusion continued for about thirty-five minutes, when it is uncovered and skimmed with care, and the contents are run into a mould of moist sand or metal. The material which results may be cast at such a temperature that any ornamental form may be given to it. It is very fine-grained, and is also damascene, malleable, and capable of taking a very brilliant polish. When tarnished by oxidation, its brilliancy can be restored by a little acidulated water. If tin be employed instead of zinc, the alloy will be still more brilliant.

. COMPOUNDS OF GOLD.—Apart from the alloys of gold, the only chemical compounds of this metal possessing any importance, are the chlorides, the oxides, and a substance known as the *purple of Cassius*, of which the composition is still somewhat obscure.

Chlorides of Gold.—Gold forms two compounds with chlorine,—a protochloride, $Au\,Cl$, and a terchloride, $Au\,Cl_3$. The latter is the most important chemical compound of the metal, and from it nearly all the other useful preparations of gold are made. It is prepared directly by dissolving gold in nitro-hydrochloric acid. On evaporating the solution, the terchloride may be obtained in ruby-red prismatic crystals, which are very fusible, and deliquesce on exposure to the air. It is very easily decomposed by heat, light, organic substances, and all deoxidizing or reducing agents. Hence the fingers or writing paper, if washed over with the solution, become stained of a violet color when exposed to the sun's light; and hence also its occasional use in photography. It is soluble in water, in alcohol, and in ether; and the latter solution, as already stated, is sometimes used for gilding steel. When heated to about 350°, the terchloride is transformed, by the expulsion of two-thirds of the chlorine, into a pale-yellow sparingly soluble powder, which is the *protochloride.* This is an unstable compound of no importance in the arts. At a red heat it loses its chlorine entirely, and metallic gold remains.

The terchloride is the usual and most convenient form of obtaining a solution of gold, and examining its properties in that state. The different reagents by which pulverulent gold may be precipitated from this solution, have been already mentioned. It is by this means that gold is obtained in a state of chemical purity.

Oxides of Gold.—The oxides of gold correspond to the chlorides, and are obtained from them,—the protoxide, $Au\,O$, from the protochloride, and the teroxide, $Au\,O_3$, from the terchloride. The *protoxide* is obtained as a dark green powder by precipitating the protochloride by a dilute cold solution of potassa. It is permanent at ordinary temperatures, but a heat bordering upon 480° decomposes it into metal and oxygen; kept in contact with a solution of potassa for some time, it alters to metallic gold and the teroxide. When digested with ammonia, it forms fulminating gold. The *teroxide* which possesses acid properties, and is therefore frequently termed *auric acid*, is the only well-known oxide of gold; it is usually prepared by digesting a solution of the terchloride of gold with pure magnesia, washing the precipitate with water, and removing the excess of magnesia by dilute nitric acid; but Wagner recommends the following process:—Dissolve one part of gold in the usual way, render it quite neutral by evaporation, and re-dissolve in twelve parts of water; add to the solution one part of carbonate of potassa dissolved in twice its weight of water, and digest at about 170°. Carbonic acid gradually escapes, and the hydrated teroxide subsides, of a brownish-red color. After being well washed, it is dissolved in colorless nitric acid of specific gravity 1·4, and the solution decomposed by admixture with water. The hydrated teroxide is thus obtained nearly pure, and is rendered anhydrous by a temperature of 212°. In the state of hydrate it is yellow, but when anhydrous it is nearly black. It is insoluble in water, is very readily reduced by solar light, and at a temperature of about 470° it is resolved into metallic gold and free oxygen. It is quickly dissolved in hydrochloric acid, yielding the common solution of gold; but although it is likewise taken up by strong nitric and sulphuric acids, it forms no true salts or definite compounds with these or with any acids containing oxygen: so slight is the affinity, that the oxide is quickly precipitated by the addition of water. The hydrated teroxide, however, readily combines with the alkalies, apparently forming regular salts, which are termed *aurates*.

Figuier gives the following method in preference to the above, in consequence of its yielding a larger product, and at the same time *a purer oxide*. Dissolve one part of gold in four of aqua regia, and evaporate to dryness on the sand-bath at a gentle heat; wash the dry residue with water, till the undecomposed terchloride of gold is removed, and add a further quantity of aqua-regia to the residue, which consists of metallic gold and protochloride; after solution, evaporate and wash as before, and repeat the process till the whole of the metal is obtained as neutral terchloride. Add the various liquors together, and then an excess of potassa, till there is a strongly alkaline reaction manifested on testing with turmeric paper. The menstruum becomes turbid, but before the teroxide of gold precipitates to any appreciable extent, chloride of barium is added. This causes the deposition of a canary-colored aurate of baryta. When the precipitate begins to present a whitish aspect, the addition of the chloride of barium is discontinued; the aurate is washed by decantation till sulphuric acid fails to show that baryta is contained in the washings, after which it is acted upon by dilute nitric acid, with the view of dissolving out the baryta. To effect the latter completely, it is necessary to raise the temperature to ebullition. As in the previous case, the nitrate of baryta is removed by decanting the liquor, and the several succeeding washings, till an acid reaction ceases to be discerned with blue litmus paper. In drying the precipitate, care is necessary, since at 212° it partly decomposes. Figuier recommends the pressing of the matter between folds of bibulous paper and subsequently exposing it in a dark situation to air, till the last traces of moisture are eliminated.

Any gold which may be carried off in the washings of the aurate of baryta, described above, is recovered by adding to them sulphate of iron, after their concentration and the removal of the baryta with sulphuric acid.

The washings and solution from the separated teroxide of gold may likewise be operated upon in a similar way, only that it is necessary to remove the nitric acid before doing so. For this purpose, the liquid is evaporated, and the residue boiled for some time with an excess of hydrochloric acid till nitrous acid ceases to be evolved.

Fulminating gold may be prepared from recently precipitated teroxide, by keeping it in strong ammonia for about a day. A dark olive-brown compound is thus obtained. Berzelius assigns to it the composition $Au\ O_3 + 2\ NH_3 + HO$, while Dumas gives it as $Au\ N + NH_3 + 3\ HO$. The Editor considers the former the more simple and probable view of its proximate composition, that is, regarding it as a diaurate of ammonia, and not a nitride of gold. A similar detonating compound is obtained when the terchloride is digested with an excess of ammonia; this is the ordinary mode of procuring fulminating gold. It subsides in the form of a yellow precipitate, the fulminating ingredient of which appears to be identical with that obtained from the teroxide. This compound may be dried at 212°; but friction, or a heat suddenly raised to about 290°, produces a violent detonation. The best way is to dry it in the open air, and to make it only in small quantities at a time. Fulminating gold, however, has no application in the arts, in which respect it differs essentially from the following.

Purple of Cassius.—When a mixture of protochloride and perchloride of tin very much diluted, is added drop by drop to a dilute neutral solution of terchloride of gold, a flocculent purple deposit takes place, which has been termed *purple of Cassius*, from the circumstance that the method of preparing it was first described by Andreas Cassius of Leyden and his son, in 1685, under the name of *gold purple*. It may likewise be prepared by fusing together 150 parts of silver, 20 of gold, and 35·1 of tin, and acting on the alloy with nitric acid, which dissolves out the silver, and leaves a purple residue containing the tin and gold. To prevent the oxidation of the tin during the fusion, the three metals should be projected into a red-hot black-lead crucible, which contains a little melted borax. Fuchs states that the finest purple is produced by mixing a solution of sesquichloride of iron with aqueous protochloride of tin, till the yellow color is converted into pale green, and precipitating the gold solution with the mixture thus formed; he adds that the protochloride of iron in the liquid does not affect the product. This substance, in the moist state, is dark purple-red, and after drying, brown. Its true nature and composition have given rise to much discussion. According to some authorities, it contains metallic gold with hydrated stannic oxide;

according to others, the gold is oxidized. BERZELIUS concluded from the researches of M. FIGUIER, that it consists of a hydrated double stannate of gold and tin, as expressed by the formula,—

$$\text{Au O, Sn O}_2 + \text{Sn O, Sn O}_2 + 4\ \text{HO}.$$

It is evident, as TURNER has remarked, both from the color of the compound, and its solubility in ammonia, that it is not a mechanical mixture of metallic gold and peroxide of tin, nor can it well be regarded as a chemical compound of these ingredients, since no definite combinations of that nature are known to chemists. The more probable supposition is, that it is a hydrated double salt, composed of peroxide of tin as the acid, united with protoxide of tin and binoxide of gold as bases, in such proportion that the oxygen of the gold exactly suffices to convert the protoxide into peroxide of tin. On this hypothesis, its composition would be expressed by the formula,—

$$2\ (\text{Sn O, Sn O}_2) + (\text{Au O}_2,\ \text{Sn O}_2) + 6\ \text{HO}.$$

Purple of Cassius is decomposed by the acids, but is not changed by the action of light. Hence it is somewhat extensively employed in the arts, chiefly for coloring glass and porcelain. When mixed with a little borax or some fusible glass, and applied to the surface of china, it imparts to it a beautiful rose or a rich purple color. Its different applications as a coloring material have already been explained in the articles ENAMELS and GLASS. It is remarkable that the oxide of tin does not appear to be essential, since even finely-divided metallic gold alone will give the same tint of purple.

Burgos Lustre.—If finely-divided gold be heated with sulphur in contact with carbonate of potassa, a double sulphide of gold and potassium is formed, which resists a red heat, and is very soluble in water. This sulphur salt is likewise used for gilding porcelain, and produces the color known as *Burgos lustre.*

QUANTITATIVE ESTIMATION OF GOLD ORES AND ALLOYS.—In proceeding to determine the exact amount of gold present in an ore or alloy, it is obviously necessary to exercise the greatest caution in the sampling. Excellent advice on this point is given by Dr. PERCY in his admirable lecture on the metallurgical treatment and assaying of gold ores, delivered at the Museum of Practical Geology. Careless sampling, he remarks, can only mislead; assays of individual specimens may be accurate, but they are worse than useless if the assayer has not operated upon an *average* sample of the ore. He therefore advises the capitalist, to whom prospectuses of gold-mining schemes may be submitted, not to be allured with glittering specimens of gold ore, with assays yielding a high produce, and with the glowing statements of sanguine promoters or enthusiastic adventurers, without having ascertained on good evidence that the samples which are presented to his notice are really *average samples* of the ore, and that something like a continuous supply may reasonably be expected. If such specimens, he adds, do not represent an average, they become what the Cornish miner calls *stocking-stones*, which are at all times enticing and dangerous to the inexperienced and unwary, and never more so than in the case of auriferous ores. The sampling generally devolves upon the miner, but the assayer and metallurgist should likewise understand the business. Assayers of great experience and high integrity may occasionally, he adds, commit unintentional mistakes. Thus, a few years ago, two small pigs of lead from South America, very rich in silver, were offered for sale. They were assayed by men of very high standing. Portions had been taken from the top and bottom of each pig, with a view to obtain a fair average. Dr. PERCY had occasion to attempt to verify the report of the assayers. Portions were taken from the same parts of each pig as in the first instance; but the results did not agree with the report, nor did Dr. PERCY's assays agree with each other on taking fresh portions. It was therefore certain that the composition was not uniform, and that the portions taken for the purpose of assaying in neither case represented an average. The pigs were accordingly sent again to the same assayers. Each pig was melted separately, and while melted a sample was taken. A second report was given, which differed from the former to the extent of one thousand ounces and upwards to the ton! In the sampling of gold ores most especial care should be taken, as the precious metal exists irregularly diffused through the mass, in particles of very different size, and as minute errors in sampling will necessarily be greatly multiplied when the quantity of gold per ton is calculated from the assaying of, it may be, five hundred or a thousand *grains* of ore.—*Percy.*

The quantitative estimation may be made, more or less correctly, by one of four methods: 1. By determining the specific gravity of the ore or alloy; 2. By the touchstone; 3. By chemical analysis, or the *wet method* of assaying; and 4. By the metallurgical, or *dry method*, in which fire is the principal agent. The first two afford only approximations, and the second is applicable only to alloys of gold; but both may be useful when circumstances render impossible or inconvenient the performance of an exact assay by the wet or dry method.

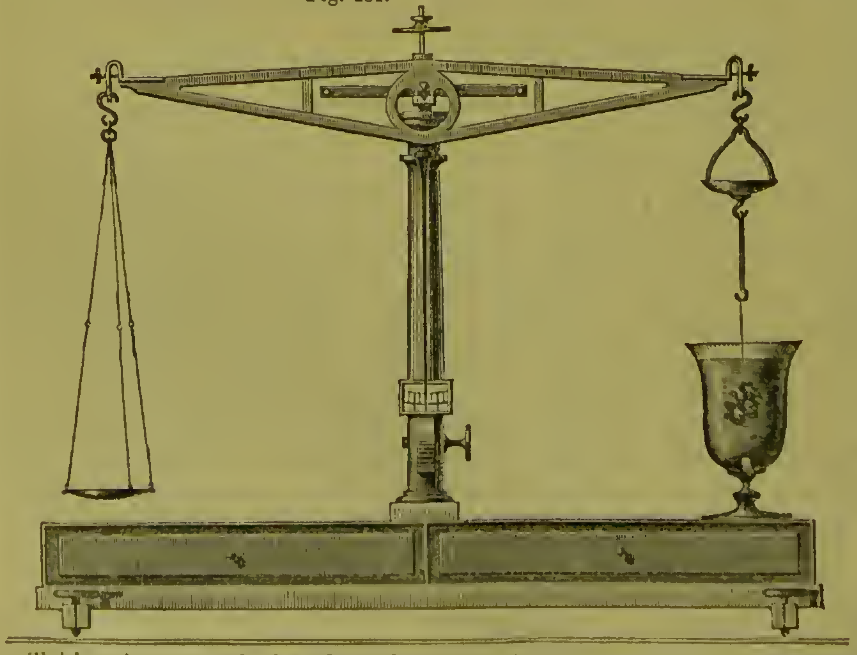
1. *Quantitative Estimation by Specific Gravity.*—It is evident that the high specific gravity of gold, in which it is exceeded only by platinum, not only affords facilities for separating it, by means of washing, from other matters, but also for estimating approximatively the amount in which it is present in any ore or mineral of known composition. The nature of the other ingredients being ascertained, and consequently their weight or specific gravity, the additional weight must be due to the presence of gold, and hence its amount may be calculated. Unfortunately, this quantitative test is rarely applicable to alloys, for experiment proves that an alloy composed of two metals has seldom a density corresponding to the mean which should be obtained by calculation from the relative amounts and specific gravities of its constituents. Thus, it has been found that alloys of gold with zinc, tin, bismuth, antimony, or cobalt, possess a greater specific gravity than the mean of the constituents, while alloys of the same metal with silver, iron, lead, copper, iridium, or nickel, have a specific gravity inferior to that of the mean. It will be seen that in the latter category are included the

metals most usually associated with gold, and hence it may be laid down as a general rule, that the specific gravity of *native gold*, containing an admixture of one or more of those metals, such as silver or copper, is *lower* than it ought to be theoretically. The following experiments by Boussingault will show that a very remarkable discrepancy exists between the calculated and true specific gravity of a *native alloy* of gold and silver. In this case, three specimens of native gold were analysed, and their specific gravities, as found by experiment, are subjoined to the results obtained by a simple theoretical calculation:—

	First Specimen.	Second Specimen.	Third Specimen.
Gold,	88·24	73·45	64·93
Silver,	11·76	26·55	35·07
	100·00	100·00	100·00
Calculated specific gravity,	18·22	16·93	16·17
Actual,	14·70	12·66	14·14
Difference,	3·52	4·27	2·03

It is evident, therefore, that an estimate formed from the actual specific gravities of these native alloys of gold, as found by experiment, would have given too low a figure for the amount of gold present. *It is remarkable, however, that these alloys acquire a higher specific gravity after being melted.* Thus, the specific gravity of the first specimen rose, after fusion, to 18·10, or very nearly to what it ought to have been by calculation. Hence it may be assumed, that in artificial alloys, a nearer approximation would be obtained to the true value by this method than with native alloys. At the same time, when, as in the case of Australian gold, the metal is nearly pure, it is evident that the amount of it present in a piece of auriferous quartz, may be deduced with considerable accuracy from its specific gravity, and as the same method is calculated to afford a useful and convenient approximation even in estimating alloys, the *modus operandi* will be explained.

Fig. 231.



Taking for granted, therefore, that the mineral proposed to be submitted to this test is a piece of auriferous quartz—the first point to be determined is its specific gravity, or its weight as compared with that of an equal bulk of distilled water; because, if this be no higher than that of common quartz, which is found by experiment to average 2·6, it will be unnecessary to proceed further; but if higher, the amount of gold present may be calculated from the difference or excess. Now, the specific gravity of a solid insoluble body, such as quartz, is very readily found by the hydrostatic balance, which in its simplest form is a common pair of scales, with a horse-hair or fine thread attached to the under surface of one of the scale pans. This balance, in its most improved form, is represented in Fig. 231. The substance of which the specific gravity is required is weighed in air, and then, being attached to the hair or thread, is immersed in distilled water at the temperature of 60° Fahr. and again weighed. The difference of the two weights will be that of its own bulk of water, and the specific gravity of the substance is the quotient of its weight in air divided by this difference. This method of ascertaining the specific gravity of irregular solids was one of the great discoveries of Archimedes, and may be thus explained:—When a body is plunged beneath the surface of a liquid, it obviously displaces a bulk of such liquid equal to itself, and, consequently, it is pressed upward or supported in the liquid with a force exactly equal to that with which the particles of the liquid were supported, when they previously occupied its place; the solid will therefore appear to have lost weight exactly equivalent to that of the bulk or volume of liquid which it occupies. Supposing, therefore, the weight of the auriferous quartz in air to be W, and its weight in water W′, the difference, W—W′, will represent the weight of an equal bulk of water, and if S be the specific gravity of the auriferous quartz, or mixture of rock and metal:—

$$S = \frac{W}{W - W'}.$$

Having thus obtained the weight and specific gravity of the compound, and knowing the specific gravity of the constituents, it is easy to calculate the amount or weight of gold present. Or, assuming G to represent the weight of the gold, and g the specific gravity of that metal: R the weight of rock or quartz, and r its specific gravity; W the weight of the compound in air, and W′ its weight in water, as before; then the weight of gold in the specimen may be found directly by the following formula:—

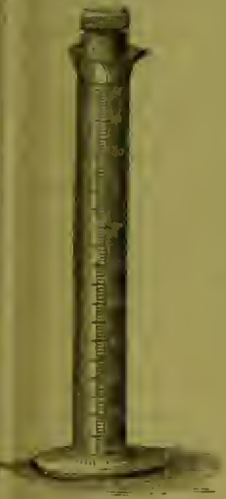
$$G = \frac{g\,[W - r\,(W - W')]}{g - r};$$

and the weight of pure quartz, if required, by this formula:—

$$R = \frac{r\,[g\,(W - W') - W]}{g - r}.$$

When the gold ore is in the state of powder or small grains, a somewhat different process must be employed to obtain the weight of a volume of water equal to that of the mineral under examination. In this case, the instrument called the specific gravity bottle, and represented in Fig. 232, is most conveniently employed. It usually consists of a cylindrical bottle, which may be graduated or not, and the stopper of which, nicely fitted by grinding, is so adjusted that it cannot sink beyond a line marked upon the neck of the phial. When the latter is filled with distilled water, and the stopper inserted, the superfluous liquid escapes by a capillary tube which is formed in the stopper for that purpose, as shown in the figure, and thus the bottle is exactly filled, and all air is expelled. Such bottles are usually made to contain precisely one thousand grains of distilled water at the temperature of 60°, so that when once filled with water at that temperature, the weight of the included liquid is known.

Fig. 232.



To ascertain the specific gravity of an insoluble powder by this instrument, the powder is first weighed in the air by means of a delicate balance, and its weight noted. It is then introduced into the bottle of distilled water, from which, when the stopper is inserted, a portion of liquid will escape, precisely equal in volume to that of the mineral introduced. The bottle, containing the water and mineral, is now carefully wiped dry, and weighed—a counterpoise equal to the known weight of the bottle having been previously placed in one of the scales. The weight found will evidently be that of the whole water and mineral together, *minus* the weight of a volume of water equal to that of the mineral. If, therefore, M be assumed to represent the weight of the mineral in air, W the weight of water which exactly fills the bottle, and W′ the weight of water and mineral in the bottle, it is evident that $M + W - W'$ represents the weight of water which has been displaced by the mineral, or in other words, the weight of a volume of water equal to its own bulk. Hence the specific gravity, S, of the mineral, or its weight in air, in terms of an equal bulk of distilled water as unity, is found by this formula:—

$$S = \frac{M}{M + W - W'}$$

Suppose, for example, that the substance to be examined resembles gold dust, and that it is found to weigh in air 150 grains. Let the bottle be assumed to contain exactly 1000 grains of distilled water, and when a portion of this is displaced by introducing the heavier mineral, let the weight of the contents of the phial be 1140 grains. In this case, $M = 150$, $W = 1000$, and $W' = 1140$. Hence, $M + W - W' = 10$; and, consequently, by the preceding formula:—

$$S = \frac{150}{10} = 15$$

instead of 19·5, the specific gravity of pure gold; from which it may be inferred that a considerable amount of the precious metal is present, though very far from being in a state of purity. The absolute amount of gold can only be estimated, provided the nature of the substances with which it is associated is known.

The trouble of weighing the contents of the bottle may be entirely avoided, and thus the operation simplified, by employing a modification of the same vessel provided with a narrow neck graduated to grains of distilled water, which will show at once the amount of liquid displaced. A phial of sufficient capacity to contain not more than from 150 to 200 grains of water, will generally be most convenient for this purpose.

2. *Quantitative Estimation by the Touchstone.*—Another method of estimating approximatively the amount of gold, not in auriferous ores, but in native gold or artificial alloys, is by the use of the touchstone—a method which may be practised with considerable advantage, when the apparatus and reagents necessary for the carrying out of a complete assay cannot be conveniently procured. It is more especially applicable to the estimation of trinkets or other finished articles, which could not be submitted to the assaying processes, either by the wet or dry method, without destroying them.

The touchstone test essentially consists in rubbing some convenient part of the object to be examined on a smooth piece of black basalt or pottery, which for this reason is termed the *touchstone*, and comparing the marks so formed with those produced by one or other of a series of small bars or needles, consisting of alloys of gold with silver or copper in known proportions. The material commonly employed as the touchstone, and generally known by that name, is a species of quartz, colored dark by bituminous matter, and of which large quantities are found in Saxony, Bohemia, and various other localities. Black flint slate will serve the same purpose. The sets of needles or bars may vary from pure gold, through a well-graduated proportion, to equal parts of gold and silver, equal parts of gold and copper, or various mixtures of all three metals in determinate quantities. The fineness of each bar is marked in carats—a mode of valuation which has been already explained.

In proceeding to make an assay by this method, the first streak obtained by rubbing the object to be examined on the touchstone cannot be safely employed to ascertain its composition, if it be a manufactured article, because, by a process previously described, the surface of jewellery is invariably rendered of a higher standard than that of the mass. The object must therefore be passed once or twice over the back or edge of the stone, in order to remove the superficial film of richer metal, before making the streak from which its quality is to be judged. Other streaks are then made successively with two or three of the needles which the assayer, guided by experience, considers to approach nearest in composition to the article under examination. In doing so, he compares not only the color of the streaks made upon the touchstone, but likewise the sensation of roughness, dryness, smoothness, or greasiness which the texture of the rubbed metals excites when abraded by the stone. When he succeeds in obtaining with one of his needles a streak which is perfectly similar in appearance to that produced by the article which forms the subject of experiment, he then moistens both streaks with nitric acid, which will affect them differently if they be not similar compositions. That which has the least gold will be most affected; on the contrary, if the gold be pure, the streak will remain unaltered. If the actions do not correspond, his experience will enable him to judge in what they differ, and will direct him in selecting another needle to submit to the same comparative test. When one has been found which agrees satisfactorily in all particulars with the metal submitted to examination, the latter is assumed to possess a similar standard of fineness to that which is indicated by the mark on this particular needle.

Nitric acid of specific gravity 1·20 is commonly employed in this operation, with sometimes an addition of about two per cent. of hydrochloric acid. Although the results obtained cannot be relied on where absolute accuracy is required, yet they afford a useful approximation, not only in estimating the value of manufactured articles which cannot be submitted to a regular assaying process, but also in obtaining that preliminary knowledge of the general composition of an alloy, which is so important to the assayer in proceeding to a detailed analysis. The touchstone is therefore of great use in practised hands, but it is of little avail in the hands of an inexperienced operator.

3. *Quantitative Estimation by the Wet Method—Analysis.*—However useful the approximations obtained from the specific gravity of an auriferous ore, or the application of the touchstone to an alloy of gold, it is evident that more exact methods are required to determine with absolute precision the value of an alloy or ore of this precious metal. Accordingly, there are two methods by which the assaying of gold ores or alloys may be conducted with perfect accuracy, and these are distinguished as the *wet* or *dry* method, according as the agency of liquid solvents or that of fluxes and fire is employed. For practical purposes, in the determination of gold, the latter process is always adopted, although in the final separation of the silver even the dry method, as now practised, involves the application of a liquid solvent.

The principles of the quantitative estimation of gold by the humid method have been already explained in detailing the laboratory process for the preparation of pure gold, and in describing the application of the tests or reagents by which its presence is detected. It is evident that any of the qualitative tests which result in precipitating the gold from its solution in aqua regia, such as protosulphate of iron, may be converted into the means of obtaining a quantitative estimation, by simply weighing the amount of ore or alloy on which the experiment is performed, and then weighing the amount of pure gold, carefully washed and dried, which is obtained in the form of a precipitate. It will therefore be unnecessary to enter into minute details on the chemical principles involved.

It may be stated, however, that if the substance to be examined be a natural or artificial alloy, composed chiefly of the pure metal, such as the gold dust of California or Australia, the quantity taken for the analysis should not exceed fifteen grains. A convenient quantity is twelve and a half grains, as it is then only necessary to multiply the result by eight to obtain the per-centage composition. In performing analyses very small quantities are taken, because it is easier to operate upon a few grains than upon a large mass; the effect of the reactions is more rapid; there is less waste of materials; and as accurate results can be obtained with a small as with a large quantity, provided sufficient precaution be taken to operate upon an average sample. If the gold be mixed with earthy or quartzose matter, so much of this should be taken as may be judged, from preliminary experiments or other sources of information, to contain the amount of native gold above-mentioned; and this must be triturated in a mortar with great care before subjecting it to the action of the aqua regia—a precaution of less importance in merely testing for gold, but absolutely necessary and essential when it is required to ascertain the exact amount of the precious metal present; for, unless the quartz be reduced to a state of the most minute division, it is evident that much of the gold remaining enveloped in the quartz will escape the action of the acid.

Whatever the precise amount taken, the ore or alloy to be examined must be weighed with extreme accuracy, and then introduced into a Florence flask or any other convenient glass vessel for boiling liquids. Supposing the compound to contain from twelve to fifteen grains of native gold, about an ounce of aqua regia is now poured upon it; the flask is then placed on a retort-stand or sand-bath, and the mixture is allowed to digest at a moderate heat for about half an hour. At the end of that time the gold will be completely dissolved, and the silver, if any be present, will be found in the form of an insoluble chloride, mixed with the silica at the bottom. The heat may then be increased under the flask, and the solution boiled off until it is diminished to about an eighth or tenth of its original quantity. At the same time a little hydrochloric acid should be added occasionally for the purpose of expelling or decomposing the nitric acid, the presence of which is injurious in the after part of the process. The addition of a little carbonate of soda will serve the same purpose. The reader will recollect that the function of the nitric acid is merely to liberate the chlorine, which is the real solvent of gold.

When the evaporation has been carried sufficiently far, three or four ounces of water should be added, after which the contents of the flask must be allowed to remain in perfect rest until the undissolved matter has completely subsided, and the supernatant fluid is quite clear. The latter is then to be carefully decanted or filtered off, and to the residue about an ounce of fresh water must be added, left to stand till clear, again decanted or filtered; and this operation repeated five or six times, always adding the later washings to the first portion of fluid. The solution of gold now obtained will be very dilute. Add to it, therefore, a few drops of hydrochloric acid, and then introduce the protosulphate of iron, which, when the liquid is well stirred, will speedily precipitate the whole of the gold in the form of a brown powder. If oxalic acid be used for the same purpose, the liquid ought to be boiled. When the whole of the precipitate appears to have settled to the bottom, a few drops of the clear supernatant liquid should be taken out on the end of a rod, placed upon a surface of clean white porcelain, and tested with a drop of the solution of protochloride of tin. If no purple precipitate be formed, it is a proof that the whole of the gold has been thrown down. If a dark brown coloring, but still no subsidence, be produced, this will indicate the presence of platinum. If any precipitate be observed, more of the sulphate of iron or oxalic acid must be added to effect a complete precipitation of the gold contained in the solution.

When the pulverulent gold has entirely deposited, the liquid must be decanted or filtered off with the greatest precaution. Care must be taken that not the smallest particle of the gold powder is allowed to pass away with the liquid. A little hydrochloric acid, which must be quite free from any admixture of nitric acid, is then to be poured upon the precipitate. This will remove any iron or other metallic impurities without dissolving the gold. The latter is then to be washed, at least six times, with successive portions of distilled water; and lastly, it is transferred to a small porcelain or platinum crucible, in which it is heated over a spirit lamp, till the last portions of water are expelled. It ought, in fact, to be raised to a red heat, or even to be fused with a small quantity of borax and nitrate of soda, as formerly recommended, to expel the last traces of chloride of silver.

The pure gold thus obtained is then to be placed in a watch-glass or small capsule, and accurately weighed in a pair of delicate scales, which should be capable of turning with a difference of at least one-hundredth part of a grain. Instead of first counterpoising the dish or capsule, and then adding weights to counterpoise the gold, it is better to begin by placing the capsule *containing the gold* in one pan, and counterpoising both by means of sand, or some other convenient material placed in the other. The gold is then removed from the dish, and weights put in its stead sufficient to restore the equilibrium. The number of grains and fractions of a grain required for this purpose will accurately represent the weight of the gold; and in this method of *weighing by substitution*, as it is termed, any risk of error arising from the possible inequality in length of the two arms of the balance will be entirely avoided.

Supposing the gold to weigh exactly 10·75 grains, and that the amount of alloy submitted to experiment was 12·5 grains, or the eighth part of one hundred, it is evident that $10{\cdot}75 \times 8 = 86$ is the per-centage of pure gold present.

4. *Quantitative Estimation by the Dry Method—Assaying.*—The fourth and last method of estimating the amount of gold in an ore or alloy, is by the use of fluxes and fire. It is therefore termed the *dry method*, and formerly even the separation of the silver was effected without a liquid solvent, by one or other of the dry processes described in connection with the operation of parting on the large scale; but now the agency of an acid solution is employed in the last part of the process.

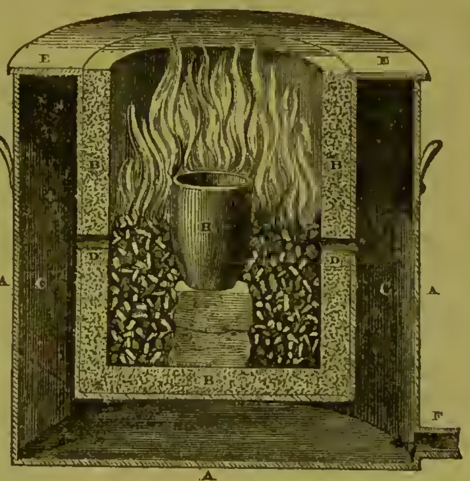
This metallurgical method, to which the name of *assaying* is strictly confined, when not otherwise expressed, is that uniformly practised at the Mint, and other regular assaying establishments, being not only more expeditious than the wet method, but admitting of a greater number of assays being conducted simultaneously. The wet method is useful for special or occasional assays in the laboratory, where assaying furnaces, cupels, *et cetera*, cannot be kept constantly in requisition. On the other hand, the dry method is the best where assaying is practised as a business, and where all the apparatus required is therefore in constant efficiency. This method consists in the following processes: 1. Fusion, to separate earthy and other gross impurities, which may be either performed in a crucible by means of oxide of lead, or by the method of *scorification* with metallic lead. 2. Cupellation, to remove the copper and other base metals by oxidation and absorption. 3. Parting by inquartation, or separation of the silver from the gold, by dissolving the former metal in nitric acid.

From this enumeration of the different operations which constitute the process of assaying by the dry method, it will be seen that this process is nothing more than a miniature representation of the smelting and refining operations already described. It will therefore be unnecessary to explain the principles on which this important department of the subject is founded, as those already enunciated in reference to the smelting and refining of gold ores, apply equally to the assaying of these ores, as well as of artificial alloys. The principal difference between the two cases consists in the fact, that the assayer operates upon a few grains instead of large quantities, while, at the same time, he must exercise the utmost precaution in attending to the weight and proportions of his materials.

Fusion with Oxide of Lead.—Assuming, as before, that the ore to be assayed is gold quartz, it must first, as in all other cases, be reduced to a fine powder, by triturating in an iron mortar. This operation is much facilitated by heating the quartz to redness, and plunging it in cold water. Having pulverized a few thousand grains, it is usual to make at least two assays of the sample, to test the correctness of the result. For each of these weigh five hundred or a thousand grains, according to the richness of the ore, and mix intimately on a clean surface of glass, or highly-glazed writing paper, with about the same weight of litharge or red lead, half the weight of dry carbonate of soda, and five per cent. of finely-powdered charcoal. The precise quantities are not very important; but it is better that the carbonate of soda should be in excess, than that it should fall short of the above proportion. This mixture is introduced into a Cornish or black-lead crucible, of which it should not fill more than two-thirds the capacity; it may then be covered with a thin layer of borax, and is afterwards fixed solidly in the assay-furnace, by surrounding it with fuel.

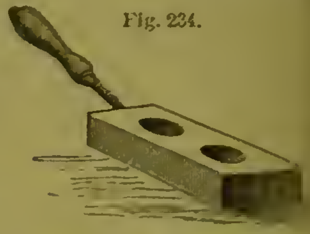
Furnaces proper for assaying are of several different kinds, and the required temperature may be obtained in them either by supplying an artificial blast of air by some blowing apparatus, or by connecting the furnace with a chimney sufficiently high to establish a strong natural draught. When the materials for its erection can be obtained, the ordinary wind-furnace is to be preferred. This is represented and fully described, in connection with the assaying of copper ores, at page 498, vol. I., to which the reader is referred. For the travelling assayer, however, a portable apparatus is required, and in this respect Selfström's blast-furnace offers peculiar advantages. This consists of two cylinders of sheet-iron, placed one within the other, as represented in the annexed drawing, Fig. 233. A represents the outer cylinder, which answers the purpose perfectly well when not larger than a man's hat; and B the inner one, lined with a coating of fire-clay about an inch in thickness. Both cylinders are provided with a bottom, and are fixed together at the top, air-tight, by a horizontal hoop or flat ring of metal, E E, in such a way as to leave an equal space, C C, between their sides and bottoms. The interior cylinder, B B, is pierced at about the middle of its depth with eight holes, D D, which pass through the lining of fire-clay, and all point to the centre of the furnace, where the crucible, H, is placed on a piece of fire-brick, kept in its position by a little fire-clay, and surrounded with fuel. For a small furnace of this kind charcoal must be employed as fuel, and should be broken into pieces about as large as a walnut. The air is blown into the opening, F, by means of a double-action bellows; or a simple rotating fan, like that employed for domestic fires, may be used. By this means the air is compressed into the space C, where it is partially heated, and is thence driven in a steady equable current through the holes D D, into the cavity of the furnace. The heat which may thus be produced with a furnace having an internal diameter of not more than six inches, is so intense as to be capable of melting manganese, or several ounces of cast-iron, with the greatest ease.

Fig. 233.



To proceed with the fusion. It has been stated that the mixture above-mentioned, when introduced into the crucible, should not fill more than two-thirds of its capacity. This precaution is necessary on account of the effervescence which will take place, owing to the displacement of the carbonic acid from the carbonate of soda by the silica, and the combination of the carbon with the oxygen of the litharge. The heat is continued till perfect fusion is effected, and towards the last the temperature is raised to bright redness, until no further effervescence occurs, and a clear liquid homogeneous slag is obtained. The crucible must then be immediately removed from the fire, otherwise the unreduced litharge would be liable to cut through the pot; and as dexterously and rapidly as possible, the slag, which constitutes the upper portion of the contents, is poured into one of the two hemispherical cavities of a cast-iron ingot-mould, Fig. 234, and then the lead, with adhering slag, into the other. If any particles of lead are found attached to the slag which is poured into the first cavity, they must be carefully separated by trituration and washing, and added to the button of lead in the other cavity. The latter is then taken out, and struck carefully on the side, on a bright anvil, with a hammer, to detach any portions of slag that may still adhere to it. Sometimes the crucible is broken to extract the button of lead, but this may be avoided by the method above described, if executed with sufficient dexterity. The whole of the gold, with any silver that may be present, remains in the lead, which is then subjected to the process of cupellation.

Fig. 234.



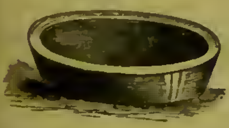
The proportion of oxide of lead to be used in the fusion will necessarily vary with the amount of oxidisable substances present; but this compound should in all cases be added in excess, since, if the slags retain any traces of an alkaline sulphide, these will retain a part of the gold. Phillips states that for the assay of iron pyrites about thirty parts of oxide of lead are necessary, whilst for mispickel, zinc blende, copper pyrites, grey cobalt, and sulphide of antimony, from fifteen to twenty-five times their weight only may be employed. When auriferous pyrites is the subject of examination, it must first be reduced to fine powder, and then roasted in a shallow dish of refractory clay, heated to low redness in a large muffle, until the odor of burning sulphur ceases to be evolved. As the sulphur burns away, the temperature is gradually raised to bright redness. The pyrites is thus converted into oxide of iron. Of this product one thousand grains or more may be taken, and mixed with five hundred of dry carbonate of soda, three hundred to five hundred of litharge or red lead, with five per cent. of charcoal, or the same quantity of granulated metallic lead without charcoal, and lastly, about five hundred of dried borax. This mixture is heated, introduced into the crucible, and fused as for quartz or other common ores. The fuel should be either charcoal, coke, or anthracite. For small portable furnaces, such as Selfström's, charcoal is employed, but anthracite is found to be well adapted for the air-furnace, and is characterised by the power of producing an intense heat in a short time, over a space confined to a few inches above the bars.

The principal objection to this method of assay is the large amount of lead which is produced for cupellation, since pure iron pyrites affords, when thus treated, eight and a half parts of lead, whilst sulphate of antimony and grey copper ore yield from six to seven parts. This inconvenience, as well as the trouble of roasting, may be avoided by the cautious and gradual addition of nitrate of potassa, which effects the partial oxidation of the mineral, and enables the skilful assayer to procure a metallic button of almost any required weight. The nitre, however, if employed in excess, would determine the oxidation of all the metallic and combustible substances contained in the mineral, except the gold alone, which is never present in sufficient quantity to form a button. The exact amount of nitre to be added must depend on the nature and richness of the ore. As a general rule, it may be stated that two and a half parts of nitre are sufficient to completely oxidise one part of iron pyrites, and that one and a half and two-thirds their weight, in the case of sulphide of antimony and galena, are sufficient to produce the same effect on these ores.

Alloys of gold containing *tin* and *zinc* must likewise be fused, before cupellation, with nitrate of potassa, to oxidise these metals; and by adding about sixteen parts of lead, when the mixture is quite melted, they are separated in the state of slag or scoria, leaving, as before, a button of lead containing the whole of the gold, which is now ready for being cupelled. But before describing this part of the assaying process, the method by scorification, which is often preferred to that of fusion with oxide of lead, will be briefly explained.

Method by Scorification.—Scorification, or, in other words, the conversion of the silica and other impurities into a scoria, is simply another method of fusion, in which, however, metallic lead, instead of its oxides, is employed; and the oxidation of the various substances to be removed is produced by the aid of atmospheric air, whilst the litharge necessary for the fusion of the earthy and silicious matters is formed by the oxidation of a portion of the metallic lead. For this operation, instead of a crucible, a shallow cup-like vessel, termed a *scorifier*, is employed. This vessel, the form of which is represented in Fig. 235, should be made of refractory clay, and be as compact in structure as possible, in order to resist the corrosive action of melted litharge. The scorifier with its contents is heated in the muffle of an ordinary assay-furnace, and as many assays may be introduced at one time as there is room for in the muffle.

Fig. 235.



A very convenient furnace for this purpose, as well as for the subsequent process of cupellation, is shown in elevation and vertical section in Figs. 236 and 237, and the form of the muffle is represented in Fig. 238. This last apparatus is a small arched vessel of fire-clay, closed at one end, and furnished with small holes or perpendicular slits in the sides and closed extremity, to allow of the free circulation of air through the interior. It is introduced by the opening, A, into the furnace, which is made of sheet-iron lined with fire-clay; and when adjusted in its place—as shown in Fig. 237—it is supported at one end by a shelf at the back of the furnace, while the other or open extremity exactly fits the opening, A, to the sides of which it is carefully luted by a little moistened fire-clay. In this position it is surrounded with ignited fuel, by which it is equally and readily heated on all sides; while the openings in its end and sides admit of the passage of a current of air into its interior, and the draught is kept up by the addition of a long chimney or funnel, F, so that the muffle is constantly traversed by a highly oxidising current. The ledge around the chimney is intended for drying the scorifiers or cupels before introducing them into the muffle. In lighting the furnace, a little ignited charcoal is first introduced by the opening, C, and the body of the furnace above and below the muffle is afterwards well charged with the same fuel, or with good hard coke broken into small pieces. The whole of the openings are then closed by means of their slides or lids, with the exception of the ashpit, D, which is left open to supply the requisite draught.

Fig. 236.

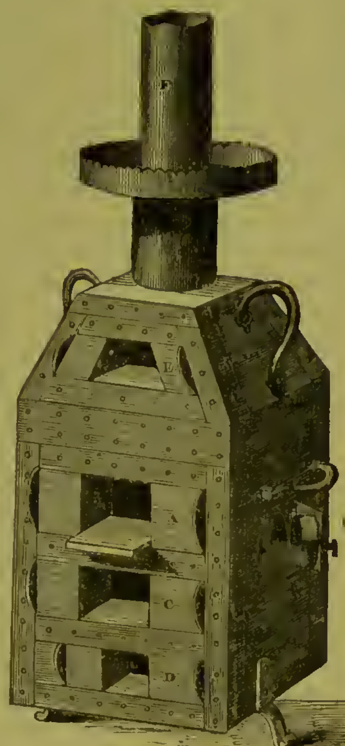


Fig. 237.

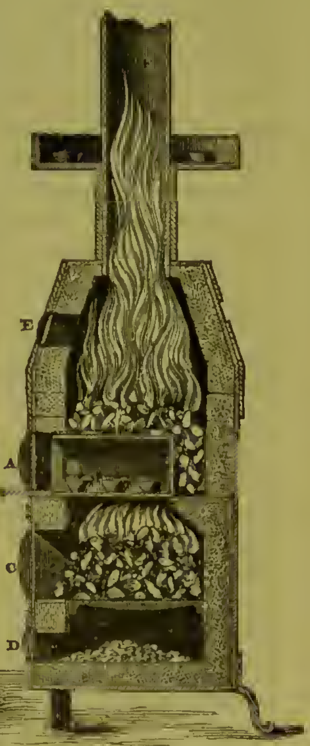
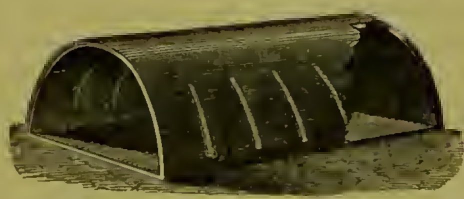


Fig. 238.



Before introducing the ore into the scorifiers, it is reduced to powder, and a determined weight of it is intimately mixed with several times its weight of finely-granulated lead, free from silver. The scorifiers charged with this mixture are then placed in the muffle, and the door at the mouth being closed, they are strongly heated in the muffle during a quarter of an hour. By this time the lead will be completely melted, and the mouth of the muffle is again opened. The scorifying process now proceeds in consequence of the current of heated air which passes through the muffle; in other words, the lead is oxidised, and the foreign metals present, whether in combination with sulphur or oxygen, are attacked and dissolved in the litharge in proportion as this oxide is formed. At first the slags are frequently solid, but gradually become soft, and more and more liquid in proportion as the quantity of oxide of lead increases. Towards the conclusion of the operation, the muffle is for a short time strongly heated to render the slag or scoria completely liquid. When a small iron rod, previously heated to redness and then placed in the mixture, is found, on being withdrawn, covered with a slight film of scoria which runs clean off, the scorification is known to be sufficiently advanced. The scorifiers are then successively withdrawn from the muffle by means of tongs, and the contents are rapidly poured into a circular ingot-mould of the form represented in Fig. 234. When cold, the adherent litharge is detached from the button of lead by a few blows with a hammer. This button contains all the gold and silver which may have been present in the ore, and which are subsequently separated from the lead by cupellation.

If the ore is poor, the whole of the precious metals contained in a large quantity may be concentrated in one small button of lead, by repeating the process on a fresh portion of ore mixed with a suitable quantity of lead, and introducing into this assay the button first obtained. A second button of the same weight as the first, and containing all the precious metals from the two quantities of ore, will thus be procured. The same process may be repeated a third, fourth, or any number of times, till the button of lead last obtained becomes as rich in the precious metals as may be required. It is necessary, however, that a certain amount of lead should be present, with a view to the next process, that of cupellation. In many cases so much as eight times the weight of the ore is employed, but the button may be reduced by a single operation to one-sixth or even to one-eighth of the original lead. Indeed, it is the highest recommendation of this process, as compared with the method by fusion with litharge, that however small may be the proportion of lead, the slags produced never contain any oxy-sulphides at the close of the operation, and, therefore, they seldom retain the slightest trace of either gold or silver. The process of scorification has therefore been justly characterized as one of the most exact methods that can be employed —simple, effective, and applicable to the assay of all kinds of auriferous and argentiferous ores, without exception.

Cupellation of the Assay.—The process of cupellation on the large scale has been already described. When applied to assays the principle is the same; but in this case the whole of the melted litharge and other oxidised matters are removed by absorption into the cupel; whereas it has been shown that, in operating on large quantities, the cupel is soon saturated, and the greater part of the litharge and other oxides are allowed to run away, or are expelled by the current of air which exerts the oxidising action.

The cupels for assaying purposes are formed of the same material as those employed for refining on the large scale, and described at page 284; but they are necessarily much smaller, and are considerably simpler in the manufacture. They are made by pressing the moistened bone-earth into a mould, which consists of a short, stout cylinder, A—Fig. 239—either of cast-iron or gun-metal, open at both ends, and having the diamete of the cavity somewhat greater at the top than the bottom. Its usual dimensions are as follow:—Interior diameter at top, one and nine-sixteenths of an inch; interior diameter at bottom, one inch and a half; depth, two inches. To make a cupel, the cavity is nearly filled with bone-ash, which is first compressed slightly with the hands, and afterwards by means of the plunger, B, which is formed of the same metal as the mould, and has the lower end turned convex, so as exactly to correspond to the concave surface of the cupel. When the plunger is introduced, it is struck several times with a mallet till the bone-as is well consolidated. The plunger is then withdrawn, and by inserting at the lower and smaller end of the mould a solid wooden cylinder, which exactly fits the aperture, the cupel is readily forced out, and is then placed to dry on the ledge which surrounds the furnace chimney—Figs. 236 and 237. The diameter of the cupel—Figs. 240 and 241—is about one inch and a half, and its cup-like cavity is very shallow, being not more than three-fourths of an inch deep.

Fig. 239.

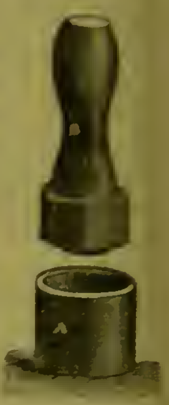
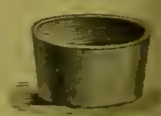


Fig. 240.



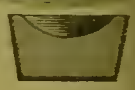
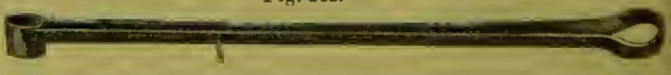


Fig. 241.

Cupellation, like the process last described, is performed by means of a muffle, Fig. 238. When the muffle has become red-hot, six or eight cupels are successively introduced into it, by a pair of light tongs of the form represented in Fig. 242; and to prevent the floor of the muffle being corroded should any of the oxide of lead be spilt on it, it is previously covered with a thin layer of pounded bone-ash. In the furnace of the Mint, the number of assays that can be made at one time is forty-five, and the same number of cupels are put into the muffle. When the cupels are introduced, the door of the opening into the muffle is closed for a few moments, while the draught-hole of the furnace is kept open till the cupels are raised to the temperature of the muffle itself. The slide is then withdrawn, and into each of the cupels is introduced, by a pair of slender tongs, a button of the alloy to be assayed.

Fig. 242.



By the previous process of fusion with litharge, or that of scorification, if deemed preferable, the earthy impurities have been removed in the form of slag or scoriæ, and nothing now remains but the gold, or a mixture of gold and silver, in combination with the lead and any other metals that may be present. The process of cupellation, as previously stated, consists in the oxidation of the lead and other oxidizable metals, and their absorption by the cupel. It is, in fact, a condition essential to the success of the assaying process that the whole of the oxides should be imbibed, and thus removed. But the power of absorption in a cupel varies according to its texture, and the care with which the material has been prepared. On an average, it may be calculated that it will absorb about its own weight of fused litharge. This, though not strictly correct, will afford a general guide to the experimenter, as regards the amount of lead which ought to be mixed with the assay. It is evident, on the one hand, that this must not exceed the absorptive power of the cupel. On the other hand, the actual amount, within this limit, must depend on the nature of the compound or alloy upon which the cupellation is to be performed; but supposing that the subject of assay is an alloy of gold and copper, the following table will give the quantity of lead required for the separation of the copper. In treating an alloy of gold and silver with copper, the quantity of lead may be somewhat diminished; but, in cupelling an alloy of copper with gold alone, a small excess of lead is not injurious, as, in consequence of the gold not being volatile, like silver, the heat can be raised and sustained for any required length of time, so as to oxidize the last portions of lead. In this table, which is adapted by Mr. T. W. Keates, from one given by Berthier for the assay of silver—the proportion of lead being altered to render it applicable to the cupellation of gold—the first two columns express respectively the quantities of gold and of copper, and the third column the parts of lead by weight required for one part of the alloy, according to its composition :—

Alloy.		
Quantity of gold.	Quantity of copper.	Proportion of lead required.
1000	0	3-10ths
950	50	6
900	100	14
800	200	20
700	300	24
600	400	28
500	500	32 to 35
400	600	32 to 35
300	700	32 to 35
200	800	32 to 35
100	900	32 to 35
0	1000	32 to 35

It must be observed that the numbers in the third column indicate multiples of one part of the alloy. It may appear surprising that, at and below the point at which the alloy contains equal parts of gold and copper, the same proportion of lead is required, whatever may be the proportion of the copper. This fact, however, has been fully verified by experience. It requires, in short, as much lead to remove the copper from an alloy of equal parts of that metal and gold as it would to carry off a quantity of copper equal to the weight of the copper and gold together. It may be added, that when the assayer has reason to know pretty nearly the composition of the alloy, it is well to insure the presence of at least two or three times more silver than gold, which is not only useful in the cupellation, to guard against loss of gold, but is necessary, as already stated, for the subsequent operation of parting.

The assays being placed in the cupels, the door is a second time closed during a few minutes, to facilitate the fusion of the alloy; and on opening it again, each of the cupels is found to contain a bright convex metallic globule, in which state the assay is said to be *uncovered*. The air is now freely admitted, and rapidly converts the lead into litharge, which, as fast as it is produced, is absorbed by the bone-ash of the cupel. While this operation is going forward, the rounded surface of the liquid button appears to be covered with bright patches and lines of color; these are produced by the thin film of oxide of lead which is constantly forming, and passing off from the centre to the edges of the assay, where it meets with and sinks into the porous matter of the cupel, leaving always a new surface exposed to the current of air which is carried by the draught through the muffle. At the same time there rises, and passes through the openings of the muffle, a white vapor, which is caused by the volatilization and combustion of a portion of lead. When this vapor is very thin, and rises with great rapidity, it is an indication that the heat is too great, and part of the draught must be stopped; on the other hand, when it is thick and heavy, and hangs sluggishly over and around the cupel, the temperature is too low, and the power of the draught must be increased.

As soon as the greater part of the lead has been thus converted into litharge and absorbed, the remaining bead of rich alloy appears to become agitated by a rapid circular movement, and the bands of color with which the surface is covered arise and vanish in quick succession. This is a sign that the process is on the point of completion, and means must now be taken to increase the heat of the furnace for a short time, so as to insure the expulsion of the last remaining portions of lead. But if silver be present in the assay, and if it be desired to estimate also the amount of that metal, the increase of temperature towards the end of the process must be of short duration, otherwise a portion of the silver would soon volatilize. Immediately before the conclusion of the process, the assay becomes somewhat dull, and the movements on its surface can no longer be observed; but after a few moments, it again suddenly lights up with a kind of flash or coruscation, and then becomes permanently brilliant and immovable,—assuming, in short, the fixed metallic lustre of pure melted gold or silver. If the cupellation has been well performed, the gold, or the mixture of the two precious metals, is now in a state of almost chemical purity.

When the phenomenon termed the *flashing*, *brightening*, or *coruscation* of the assay indicates that the cupellation is terminated, the mouth of the muffle ought to be closed for thirty or forty seconds, and then the cupel containing the button of pure metal may be drawn to the front of the muffle, and allowed to cool slowly. The refrigeration must not be too rapid, otherwise there may be very sensible loss by *spitting*, *sprouting*, or *vegetation*—an effect, however, only produced when a large proportion of silver is present, and which has been already explained in connection with the process of cupellation on the large scale. To insure gradual cooling, it is occasionally convenient to invert over the cupel containing the bead another heated cupel.

The button is detached from the cupel after cooling by a pair of fine steel forceps, and gently squeezed between the jaws of a pair of pliers, to loosen and pulverize any adhering litharge, which is finally cleaned off with a small brush made of brass wire or stout bristles. If the process has succeeded, the button should be round and bright upon its upper surface, but somewhat rough or crystalline on the part by which it was attached to the cupel, from which it ought to be capable of being removed without difficulty.

Even after cupellation, there always remains a trifling admixture of copper in the assay, which is called the *surcharge*, unless there has been present a sufficient proportion of silver. This metal greatly facilitates the separation of the copper, and when it is present in the proportion of three parts of silver to one of gold, the copper can be completely separated. This is one important reason for adding the requisite amount of silver before cupellation. But although silver is not appreciably oxidised or volatilized when melted alone, yet it is so to a certain extent in cupellation, in consequence of the presence of lead. It is, therefore, necessary to make cupellations of the buttons from ores containing silver, at the lowest heat at which the absorption of the litharge can be readily determined. But even when every precaution is used, there is always a loss of silver in cupellation; and the amount of this loss under varying conditions must be known, so as to be able to supply the deficiency in the calculation of the per-centage, as well as with a view to the next process of *parting*. The following table has been calculated for this purpose. The first column gives the weight of silver in one thousand parts of an alloy of silver and copper about to be submitted to cupellation; the second, the actual weight of silver found by cupelling an alloy of silver and copper containing the weight of silver indicated in the corresponding line of the first column; and the third, the actual loss in weight of silver:—

Weight of silver before cupellation.	Weight of silver after cupellation.	Loss of silver.
1000	998·97	1·03
975	973·24	1·76
950	947·50	2·50
925	921·75	3·25
900	896·00	4·00
875	870·93	4·07
850	845·85	4·13
825	820·78	4·22
800	795·70	4·30
775	770·59	4·41
750	745·48	4·52
725	720·36	4·64
700	695·25	4·75
675	670·27	4·73
650	645·29	4·71
625	620·30	4·70
600	595·32	4·68
575	570·32	4·68
550	545·32	4·68
525	520·32	4·68
500	495·32	4·68
475	470·50	4.50
450	445·69	4·31
425	420·87	4·13
400	396·05	3·95
375	371·39	3·61
350	346·73	3·27
325	322·06	2·94
300	297·40	2·60
275	272·42	2·58
250	247·44	2·56
225	222·45	2·55
200	197·47	2·55
175	172·88	2·12
150	148·30	1·70
125	123·71	1·29
100	99·12	·88
75	74·34	·66
50	49·56	·44
25	24·78	·22

In assaying native gold or artificial alloys, the operation usually commences by fusing the alloy in a cupel with about five times its weight of pure lead, and then adding the amount of pure silver necessary to bring the mixture to the proper composition. If the substance be in the ordinary state of the gold of California or Australia, that is, in small grains or dust, it is the best plan to envelop it in a thin sheet of lead; or a suitable quantity of perfectly pure lead may be put into the cupal and melted, and then the assay, wrapped up in a piece of thin sheet assay-lead, may be gently added to the melted lead upon the cupel. Finally, add about three times the weight of the assay in pure silver, and then proceed with the cupellation in the manner above-described. The presence of iron, tin, nickel, or zinc, in the alloy under assay, materially interferes with the success of the operation, as these metals will not pass into the cupel by the aid even of a large quantity of lead; but from their rapid oxidation, will either volatilize, or will accumulate on the surface as a sort of slag, in which particles of precious metal may be entangled. In this case the assay becomes what is technically termed *foul*, the cupel not being able to absorb the metallic oxides as fast as they are formed. To obviate this evil, the preliminary process of scorification should be resorted to, when the presence in the alloy of any of the above metals is known or suspected. A convenient weight of native gold or rich alloy to operate upon is ten to fifteen grains.

Bismuth might be used as a substitute for lead in cupellation, two parts of it being nearly equivalent to three of lead; but its higher price prevents its general use for this purpose. The lead employed must be in all cases entirely free from silver, being such as has been revived from pure litharge, otherwise it would be quite impossible to estimate the true composition of the alloy. The assay of gold furnishes results which are more accurate than those obtained in the cupellation of silver; the loss of gold by volatilization is very much smaller, and scarcely any of the metal is carried into the cupel by an excess of lead.

Parting of the Assay.—After the preceding operations, the button of alloy which remains is composed of gold and silver, not, indeed, absolutely pure, for, whatever precautions may be used, it will still retain a small quantity of lead, and frequently, also, traces of copper. For practical purposes, however, it may be regarded as a pure alloy of the two precious metals, and in this view it now only remains to separate the gold from the silver. It has been stated that, on the Continent, this is effected on the large scale by means of sulphuric acid, which, at its boiling temperature, possesses the property of dissolving silver without acting upon gold.. For analytical purposes, however, nitric acid is preferred, and is generally employed in this country, even for refining operations on the large scale.

It has been stated, also, that when silver and gold are intimately mixed together, as in an alloy, it is necessary that the silver should be present in the proportion of at least two and a half parts of that metal to one part of gold, otherwise its particles will be so enveloped and protected by those of the gold, that the nitric acid will be prevented from exercising its solvent action upon them. If, as is generally the case, the requisite proportion of silver has been introduced before cupellation, or if it is known to exist in the alloy in that proportion, then it will be sufficient to subject the mixture at once to the action of the acid. But if the silver be present in a less or much greater proportion, then, as a preliminary step to the operation of parting, the alloy must be brought to the proper standard, either by the addition of the necessary quantity of pure silver, or by adding more gold, as the case may be; for if the proportion of silver exceed three parts, the gold will be precipitated by the acid as a dark powder, instead of retaining the more convenient form of the alloy subjected to treatment; and thus an accurate estimation of the amount of gold present will be rendered considerably more difficult.

On the whole, the operation of parting is found to succeed best when the alloy contains a little less than three parts of silver to one of gold. Hence, in all cases where much exactness is required, the addition of silver, if necessary, must be so managed as to agree as closely as possible with this proportion; and from the circumstance, that when the relative quantities of the two are so adjusted, the gold is present in the proportion of about one-fourth of the mass, and the silver in the proportion of three-fourths, the operation of bringing the alloy to the proper standard by the requisite addition of the latter metal, is termed *inquartation.* The quantity of silver required can only be known by a previous approximate experiment by the wet method of examination, or by the use of the touchstone.

Assuming that the proper proportion already exists in the button of gold and silver obtained by cupellation, it is first hammered out upon an anvil into a small disc about the size of a sixpence, and annealed by heating it to redness. It is then passed between a pair of laminating rollers, by which its thickness is reduced to that of an ordinary address card, or about one-eightieth of an inch, after which it is a second time annealed. These operations render it sufficiently flexible to allow of its being twisted into a small spiral coil or *cornet*, by rolling between the finger and thumb. The cornet thus obtained is then introduced into a small parting-flask of the form represented in Fig. 243, which contains about an ounce of nitric acid of specific gravity 1·180. The acid must be perfectly *free from chlorine*, and must always be carefully tested to ascertain this point by adding to it a drop of solution of nitrate of silver, which, if chlorine be present, will instantly render it milky. Instead of the flask represented in Fig. 243, a small bulb-shaped matrass is frequently used, and is now generally adopted by the best assayers of bullion, both on the Continent and in this country. Common Florence oil flasks, or smaller vessels of the forms represented in Figs. 244 and 245, will be found very convenient. When the cornet has been introduced, the flask with its contents is gently heated to nearly the boiling-point. Effervescence will now take place, with a brisk evolution of nitrous fumes, and the silver will be gradually dissolved, leaving the gold in the form of the original cornet, but porous, very brittle, and of a deep blackish-brown color. When the effervescence has entirely ceased, the flask is removed from the heat, and the solution is carefully decanted off, without letting the cornet of gold fall out. The latter is then washed by pouring distilled water upon it, which, after standing for a couple of minutes, is again poured off. The gold will still retain some traces of silver, and in order to remove these, the cornet is again boiled with stronger nitric acid, of specific gravity 1·280, and this operation may even be repeated a third time, to remove the last portions of silver, which exist as a surcharge. In the second and third boilings, which may each be continued for ten or fifteen minutes, it is well to introduce into the flask a small fragment of charcoal, to prevent the ebullition from taking place with sudden bursts, otherwise the action may be so violent as to break the cornet, which it is desirable to avoid.

Fig. 243.

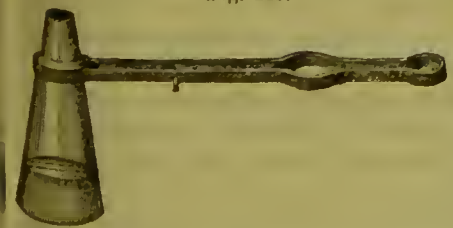


Fig. 244.

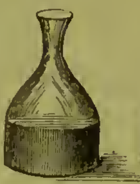
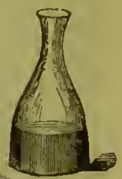


Fig. 245.



The last acid having been poured off, the flask is completely filled with distilled water, and a small, smoothly-finished, porous clay crucible is placed over the mouth of it. The two vessels, thus adjusted, are then inverted, so as to allow the cornet to fall gently through the water into the crucible, and by a dexterous movement of the hand the flask is withdrawn, in such a manner as to prevent the overflow of any liquid from the little crucible. The latter is now carefully decanted into the vessel containing the silver solution, and the crucible containing the cornet is heated to redness in the muffle. Under this final heating it is not fused, but shrinks in bulk, loses its brown appearance, and assumes the peculiar color and lustre of gold; while at the same time it is rendered more compact, less brittle and fragile, and when cold, can now be removed by a pair of forceps to the scales, in which it is weighed with the same precision and care as the original alloy.

The weight of the cornet will indicate very nearly the amount of gold in the alloy if the assay has been properly conducted, but not with absolute exactness. Even when every precaution has been used, the gold contained in the cornet is never chemically pure; it still retains a very small quantity of lead and of silver, and frequently also traces of copper, in consequence of which the weight of the cornet may exceed by one two-thousandth part the true result; and when it is considered that, in assaying alloys, the quantity taken is usually not more than seven or eight grains, it will be seen that even this small error might lead to serious disappointment in estimating the proportion of gold in large masses of bullion. To ascertain the amount of the error, and thus to arrive at a perfectly correct estimate, it is usual to pass through the muffle, simultaneously with the alloys, a number of what are termed *proofs*, consisting of weighed portions of perfectly pure gold, to each of which is added a proportion of copper equal to that estimated to exist in the alloys under examination. The cornets obtained from these proof-assays are weighed, and the excess of weight over that of the gold which was introduced, indicates the amount of the correction which it becomes necessary to make for the other assays. This correction is liable to variation, according to the temperature of the furnace, and other causes; but it usually ranges from 0·2 to 0·5 in 1000.

If the quantity of silver in the alloy submitted to the operation of parting exceed by more than thrice the weight of the gold, the separation may still be effected by nitric acid, but the gold will be left in a state of powder. It may, however, be washed, ignited, and weighed in the manner described in connection with the quantitative estimation of gold by the wet method, and also in the process of parting with sulphuric acid on the large scale. Should the amount of silver be but small compared with the gold, and the assayer wish to avoid the trouble of inquartation, the alloy may at once be subjected to the action of aqua regia, when the gold will be dissolved, and the silver will be thrown down as an insoluble chloride. The clear solution containing the gold is then decanted, and when the excess of acid has been expelled by evaporation, the gold can be precipitated, as already described, by sulphate of iron.

The silver contained in the solution of the nitrate of that metal obtained in the common process of parting, may readily be recovered by adding an excess of chloride of sodium, which will throw down the whole of the silver as white insoluble chloride. This precipitate, which speedily becomes slate-colored on exposure to light, is collected, and put into a vessel containing water acidulated with hydrochloric acid; some zinc or iron is introduced, and the silver is rapidly restored to the metallic state, in the form of a dark-grey powder. When this powder is washed with water, dried, and fused in a crucible, the silver assumes its natural appearance, but is very brittle. Its malleability is restored, however, by simply re-melting.

Physiological Effects, *et cetera.*—Gold, says Pereira, like other metals, has been frequently supposed to be inert while it retains its metallic condition, but in this, as well as in some other instances, the accuracy of the assumption has been denied. Both Chrestien and Niel, as well as other writers, assert that finely-divided metallic gold—*pulvis auri*—produces the same constitutional effects as those caused by the various preparations of this metal, but in a milder degree, while it excites little or no irritation. It is said to promote the secretions of the skin, kidneys, and salivary glands.

It has been employed as an antivenereal and antiscrofulous remedy, by Chrestien, Niel, and others, with considerable success. It is said to be preferable to the other preparations of this metal in delicate and nervous subjects, females and infants. Gold-leaf—*aurum foliatum* seu *lamellatum*—is used by dentists for filling decayed teeth, and was formerly employed by apothecaries for covering pills—*ad inaurandas* seu *obducendas pilulas.* Silver-leaf now takes its place. It has been administered internally in doses of from a quarter of a grain to a grain three or four times a day. Chrestien used it by way of friction on the tongue and gums. Niel employed it endermically—that is, applied it to the skin deprived of the epidermis—in the form of ointment composed of one grain of gold and thirty grains of lard.

Teroxide of gold is sometimes used internally, in venereal and scrofulous diseases, in doses of from one-tenth of a grain to a grain, made into the form of pills with mezereon.

The terchloride of gold, the preparation of which is described at page 293, acts, according to Orfila, as a corrosive when introduced into the stomach of animals, but with less energy than the chloride of mercury, and destroys them by the inflammation of the coats of the alimentary canal which it sets up.

On man its effects are analogous to those of chloride of mercury. In *small doses* it acts, according to Dr. Chrestien, more energetically as a stimulant, though less powerfully as a sialogogue, than corrosive sublimate. It promotes the secretions of the skin, the salivary glands, and the kidneys. Taken to the extent of one-tenth of a grain daily, it has occasioned violent fever. Cullerier has seen one-fifteenth of a grain excite, at the second dose, gastric irritation, dryness of the tongue, redness of the throat, colic, and diarrhœa. When it promotes the secretion of saliva, it does not as mercury affect the teeth and gums. Magendie has seen violent gastritis, accompanied by nervous symptoms—cramps and pains in the limbs, agitation and loss of sleep—and afterwards great heat of skin, and obstinate sleeplessness. In *large doses*, it would probably occasion symptoms similar to those produced by the use of poisonous doses of chloride of mercury.

It has been employed, with variable success, as a substitute for mercury in the secondary symptoms of syphilis. A more extended experience of it is, however, necessary to enable one to speak of its remedial powers with confidence. In the hands of Chrestien, Niel, Cullerier, Legrand, and others, it has proved most successful.

It has also been used in scrofulous affections, bronchocele, chronic skin diseases, scirrhous tumours, *et cetera.* Duportal cured with it a case of obstinate ulceration of the face, regarded by him as cancerous, and which had resisted all the ordinary methods.

Legrand has used terchloride of gold, acidified with nitric acid, as a caustic in syphilitic, scrofulous, and scorbutic ulcers, cancerous growths, and ulcerations of the neck of the uterus.

Internally, it has been given in doses of one-twentieth of a grain, made into pills with starch. But as organic matters decompose it, it is better to use it in distilled water, or to apply it by friction to the mouth, in quantities of from one-sixteenth to one-sixth of a grain.

The whites and yolks of eggs, milk, and a mixture of wheat-flour, oatmeal, or barley, and water, are, as in the case of chloride of mercury, antidotes for an overdose of this auric compound.

The Editor is surprised to find that the above are so little used in medicine. Surely, if physicians would only daily experiment on the action of the different metals and their compounds upon the system, they might soon discover some more very valuable specifics.

STATISTICS.—Gold and silver are frequently confounded in statistical returns under the common designation of the *precious metals;* and even where the two are classed separately, it is still desirable to place them in juxtaposition, since much of the interest attaching to the subject is derived from the relation which they bear to each other. In proceeding, therefore, to state the most important facts connected with the statistics of gold, the Editor will give, at the same time, most of the corresponding facts and figures relating to silver; which will not only save the repetition of a number of tables nearly similar, but will furnish the reader with a clearer and more satisfactory view of the subject, than if the returns relating to each of the metals were tabulated separately in different parts of the work.

Much interesting information relating to the history and statistics of the precious metals is given in a work which was published by Mr. JACOB in 1831, in which he takes up the subject at the earliest period, and continues it to the year above-mentioned. Mr. JACOB shows that, in the days of Roman supremacy, the greater part of the wealth of the world continued to flow into Rome, up to the time of AUGUSTUS, when the production of gold from the Roman mines in Illyria and Spain suddenly ceased; and for a long period the world received no new accession of metallic wealth. With much labor and research, he constructed a table showing the rate of diminution to which the enormous wealth of the Augustan period was subject; and though it includes both gold and silver under one head, while at the same time its accuracy cannot be implicitly relied on, still it is sufficiently correct and instructive to merit a place in these pages:—

QUANTITY OF GOLD AND SILVER IN THE ROMAN EMPIRE.

Year.	
14	£358,000,000
50	322,200.000
86	287,980,000
122	259,182,000
158	233,263,800
194	209,937,420
230	181,943,678
266	163,749,311
302	147,374,380
338	132,636,942
374	119,373,248
410	107,435,924
446	96,692,332
482	87,033,099
518	78,229,700
554	70,406,730
590	63.364,057
626	57,027,652
662	51,324,887
698	46,192,399
734	41,573,160
770	37,415,840
806	33,674,256

From the decline and fall of the Roman empire, the portion of gold added to that already obtained was, for many centuries, not more than sufficient to supply the annual waste by wear and loss; and except the mines of Hungary and Sweden, which do not appear to have been worked before the eighth or ninth century, no important new sources of gold were opened until the discovery of America by COLUMBUS in 1492. This event was followed, in the course of the next century, by a considerable influx of the precious metals into Europe; yet a very superficial inquiry will suffice to show, that the actual amounts which were imported from Mexico and South America have been greatly exaggerated in the public mind, and sink into very humble figures when compared with the enormous treasures obtained within the last few years from California and Australia. From 1492 to 1500, America, according to HUMBOLDT, furnished to Europe, in gold and silver, not more than fifty-two thousand pounds sterling, and the entire annual amount of gold and silver obtained from America during the sixteenth century was only about half a million sterling; whereas, for the last few years, the value of *gold alone* exported from California and Australia has averaged twenty-four millions per annum. The celebrated *El Dorados* of the sixteenth century sink, therefore, into utter insignificance, compared with the recently-developed auriferous regions.

It is true, that with the discovery of the Brazil mines and other sources, the import of the precious metals from America continued steadily to increase; and from 1600 to 1700, during which period Europe obtained its supply of gold almost exclusively from the New World, the mines of the latter were estimated to have produced an amount of gold and silver equivalent to three hundred and thirty-seven millions, five hundred thousand pounds sterling, or upwards of three millions per annum. In consequence of this continued importation, the value of the coined money in Europe in 1699 has been estimated at two hundred and ninety-seven million pounds sterling. During the eighteenth century, the supply of the precious metals was still chiefly derived from the Americas. The annual produce of the mines of that quarter of the globe, at the commencement of the present century, was estimated by HUMBOLDT at eight millions, seven hundred thousand pounds sterling; and that derived from the European mines of Hungary, Saxony, *et cetera*, and those of Northern Asia, was valued by him at one million pounds sterling more, raising the total produce at that period, exclusive of Africa, to nine million seven hundred thousand pounds sterling. The *quantity* of gold produced in America was to the *quantity* of silver as 1 to 46; in Europe as 1 to 40; and the *values* of equal quantities of gold and silver were then in the proportion of 15 to 1, so that the aggregate value of the gold to that of the silver was nearly as 1 : 3; or, in other words, the annual amount of *gold alone* produced at the beginning of the present century was worth about three million two hundred thousand pounds sterling.

From 1800 to 1810 the yield of the American mines continued still to increase, and, in conjunction with that of the European and Russian mines, is supposed to have amounted in the latter year to upwards of eleven million pounds sterling, in gold and silver. But in that year began the contest which resulted in the dissolution of the connection between Spain and her American colonies, causing the abandonment of several of the mines, and a consequent decline in the production of the precious metals to such an extent, that, according to JACOB, the total average yield of the American mines, inclusive of Brazil, during the twenty years ending with 1829, might be estimated at little more than four million pounds sterling a year; being less than half their produce in 1800. Some years later, however, they again began to increase; and this, in conjunction with the recent extraordinary development of the Russian mines, raised the entire amount of gold and silver produced from all the *known* auriferous localities throughout the world, *before the discovery of California and Australia*, to upwards of twelve million pounds sterling per annum; the value of the gold to that of the silver being nearly as 5 : 6. This will appear from the following table, prepared by Mr. BIRKMYRE, showing, by approximate calculation, the annual produce in value of fine gold and silver for 1846 and 1850; the first being two years before the discovery of the rich deposits of gold in California, the latter two years after the discovery:—

Countries.	1846.			1850.		
	Gold.	Silver.	Total.	Gold.	Silver.	Total.
	£	£	£	£	£	£
California,	—	—	—	12,000,000	62,088	12,062,088
United States,	237,336	1,864	239,230	115,430	11,444	126,874
Mexico,	249,753	3,457,020	3,706,773	382,901	5,383,333	5,766,234
New Grenada,	252,407	42,929	295,336	252,407	42,929	295,336
Peru,	96,241	1,000,583	1,096,824	96,241	1,000,583	1,096,824
Bolivia,	60,337	460,191	520,548	60,357	460,191	520,548
Chili,	145,585	297,029	442,614	145,585	297,029	442,614
Brazil,	259,871	2,003	261,874	289,068	2,227	291,295
Total of North and South America,	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Russia,	3,414,427	167,831	3,582,258	4,175,860	171,817	4,347,477
Norway,	—	32,346	32,346	—	35,607	35,607
North Germany,	357	138,022	138,379	357	138,022	138,379
Saxony,	—	198,200	198,200	—	198,200	198,200
Austria,	282,750	282,654	565,404	288,708	286,971	575,679
Piedmont,	17,841	7,444	25,285	17,841	7,444	25,285
Spain,	2,498	227,499	229,997	2,498	440,210	442,708
United Kingdom,	—	109,989	109,989	—	160,000	160,000
Africa,	203,900	1,056	204,956	203,900	1,056	204,956
Borneo,	305,900	1,584	307,484	305,850	1,584	307,484
Ava,	100,000	517	100,517	100,000	517	100,517
Malacca,	72,240	374	72,614	72,240	374	72,614
Sumatra,	63,719	330	64,049	63,719	330	64,049
Annam or Tonquin,	30,585	53,460	84,045	30,585	53,460	84,045
Various countries,	50,975	33,000	83,975	50,975	33,000	83,975
Total of Europe, Africa, and Asia,	4,545,192	1,254,306	5,799,498	5,312,533	1,528,592	6,840,975
Total of North and South America,	1,301,560	5,261,619	6,563,179	13,341,989	7,259,824	20,601,813
Total,	5,846,752	6,515,925	12,362,677	18,654,522	8,788,416	27,442,788

The various countries are exclusive of China and Japan, which produce large quantities of gold and silver, the amount of which is quite unknown to Europeans.

It will be seen from the above table, that in 1846 the total value of the gold is estimated at five million, eight hundred and forty-six thousand, seven hundred and fifty-two pounds sterling; in 1850, it rises to eighteen million, six hundred and fifty-four thousand, five hundred and twenty-two pounds sterling. Mr. BIRKMYRE, however, estimates the produce of California alone in the last-mentioned year at twelve million pounds sterling—a figure so high that, notwithstanding the importance attached by MACCULLOCH to his calculations, it seems to have far exceeded the truth. This may be inferred from the following table, extracted from the *Economist* newspaper, which has the credit of deriving its statistical information from the highest official sources:—

TOTAL VALUE OF GOLD EXPORTED FROM AUSTRALIA AND CALIFORNIA IN EACH YEAR FROM 1848 TO 1856 INCLUSIVE.

Year.	New South Wales.	Victoria.	California.	Total.
1848	——	——	£11,700	£11,700
1849	——	——	1,600,000	1,600,000
1850	——	——	5,000,000	5,000,000
1851	£468,336	£438,777	8,250,300	9,157,413
1852	3,600,175	6,135,728	11,700,000	21,435,903
1853	1,781,171	8,664,529	12,500,000	22,945,700
1854	773,209	8,255,550	14,100,000	23,128,759
1855	209,250	11,303,980	13,400,000	24,913,230
1856	97,456	12,643,024	14,000,000	26,740,480
Total,	£6,929,597	£47,441,588	£80,562,000	£134,933,185

To bring down the accounts to the latest date, the following table of imports, also resting on high authority, may be added:—

IMPORTS OF GOLD AND SILVER INTO GREAT BRITAIN FOR THE FIRST SIX MONTHS OF THE YEAR 1857 WERE—

From	
Africa, ...gold	£52,000
United States, including principal imports from California, ...	3,252,000
Australia, ...	5,833,000
Brazils, ...	6,000
Mexico, West Indies, Peru, and a portion from California, ... gold and silver	3,415,000
Mediterranean, ...	543,000
Russia, ...	119,000
	£13,220,000

It will be observed, however, that these figures include both silver and gold, and indicate merely the amount of the precious metals imported into this country. But when it is considered that nearly the whole of the Australian produce is in gold, and that it is almost exclusively exported to Great Britain, the amount above stated as having been imported from that part of the world during the first six months of the present year, seems to indicate a falling-off as compared with the amount exported in 1856. This decline has been acknowledged by Australian journalists, but is attributed to temporary causes—the employment of larger numbers of the mining population than at any former period in deep sinking and in quartz mining, their consequent withdrawal from the immediate production of gold, and the protracted dryness of the season. The same writers affirm, that when the labor of the deep sinkers has been consummated, and the hoards of the shallow sinkers have passed through the process of washing, the average of the returns of the current year will be brought up to that of last. The steadiness with which the quartz reefs are being opened up at a heavy cost of labor and of money, and the large sums expended in machinery for the extraction of the metal, are deemed sure indications of the faith entertained by practical men in the hidden riches of the Australian gold mines.

On the whole, the present annual supply of gold may be roughly estimated as follows:—

Asiatic Russia, ...	£4,000,000
Rest of Asia—exclusive of Japan and China, ...	500,000
Europe, ...	300,000
Africa, ...	200,000
North and South America—exclusive of California,	1,500,000
California, ...	14,000,000
Australia, ...	13,000,000
Total, ...	£33,500,000

The annual consumption of *gold and silver* in the arts, and as coin or currency, is estimated by MACCULLOCH as follows:—

Wear and tear and loss of coin, ...	£5,700,000
Increase of currency, ...	11,400,000
Used in the arts, ...	11,200,000
Total, ...	£28,300,000

In connection with the subject of coinage, it may not be out of place to append the following tables, which would be obviously divested of much of their interest by giving the gold coinage alone:—

I. AMOUNT OF GOLD, SILVER, AND COPPER MONIES COINED AT THE ROYAL MINT, LONDON, FROM 1840 TO 1856.

Years.	Gold.	Silver.	Copper.	Total.
1840	Nil	£216,414	£3,136	£219,550
1841	£378,472	96,175	8,848	483,495
1842	5,977,051	192,852	1,764	6,171,667
1843	6,607,849	276,606	10,080	6,894,535
1844	3,563,949	626,670	7,246	4,197,865
1845	4,244,608	647,658	6,944	4,899,210
1846	4,334,911	559,548	6,496	4,900,955
1847	5,158,440	125,730	8,960	5,293,130
1848	2,451,999	35,442	2,688	2,490,129
1849	2,177,955	119,592	1,792	2,299,339
1850	1,491,836	129,096	448	1,621,380
1851	4,400,411	87,868	3,584	4,491,863
1852	8,742,270	189,596	4,312	8,936,178
1853	11,952,391	701,544	10,190	12,664,125
1854	4,152,183	140,480	61,538	4,351,201
1855	9,008,663	195,510	41,091	9,245,264
1856	6,002,114	462,528	11,418	6,476,061

II. COINAGE OF FRANCE IN EACH YEAR FROM 1846 TO 1856 INCLUSIVE, CONVERTED INTO BRITISH MONEY AT THE RATE OF TWENTY-FIVE FRANCS TO THE POUND STERLING.

Years.	Gold.	Silver.	Total.
1846	£88,000	£1,332,000	£1,420,000
1847	300,000	2,760,000	3,060,000
1848	1,600,000	4,040,000	5,640,000
1849	1,080,000	7,360,000	8,440,000
1850	4,600,000	3,120,000	7,720,000
1851	9,600,000	2,360,000	11,960,000
1852	1,040,000	2,840,000	3,880,000
1853	13,200,000	800,000	14,000,000
1854	20,480,000	80,000	2,056,000
1855	16,417,928	862,800	17,280,728
1856	20,334,076	2,168,888	22,502,964

III. ACCOUNT SHOWING THE AMOUNT OF COINAGE IN THE UNITED STATES IN 1855, CONVERTED INTO BRITISH MONEY AT THE RATE OF FOUR SHILLINGS AND THREEPENCE TO THE DOLLAR.

Mints.	Gold.	Silver.
Philadelphia, ...	£2,251,321	£301,574
New Orleans, ...	95,731	407,575
San Francisco, ...	3,739,639	34,228
Dahlonega, ...	24,815	—
Charlotte, ...	46,311	—
Total, ...	£6,157,817	£743,377

IV. BULLION EXPORTED FROM ENGLAND AND THE MEDITERRANEAN PORTS TO THE EAST—1852 TO 1856.

Years.	Gold.	Silver.	Total.
1852	£761,318	£2,494,137	£3,255,455
1853	986,574	5,695,602	6.682,176
1854	1,222,755	4,583,017	5,805,772
1855	1,191,511	7,934,129	9,125,610
1856	478,788	14,108,901	14,587,689
Total, ...	£1,640,946	£34,815,786	£39,156,732

Annexed are some of the rates of value of a pound troy of gold at different periods:—

VALUE OF THE TROY POUND OF GOLD.

Years.	£	s.	d.
1344	£15	0	0
1345	13	3	4
1347	14	0	0
1412	16	13	4
1464	20	16	8
1526	27	0	0
1549	34	0	0
1605	40	10	0
1626	44	10	0
1718	46	14	6
1817	46	14	6

which is the price at which fine gold still continues, or three pounds seventeen shillings and tenpence halfpenny per ounce.

Mr. HUNT states, that for the uses of the arts not less than one thousand ounces of fine gold are used in Birmingham alone every week, and that in the United Kingdom the weekly consumption of leaf-gold is as follows:—

	Ounces weekly.
London,	400
Edinburgh,	35
Birmingham,	70
Manchester,	40
Dublin,	12
Liverpool,	15
Leeds,	6
Glasgow,	6
Total,	584

Of this amount, he states, on the authority of an eminent gold-refiner, that not one-tenth part can be recovered; and he adds, that for gilding metals by the electrotype, and the water or wash-gilding processes, not less than ten thousand ounces of gold are required annually. One establishment in the Potteries employs three thousand five hundred pounds' worth of gold per annum, and nearly two thousand pounds' worth is used by another. The consumption of gold in the Staffordshire Potteries for gilding porcelain and making crimson and rose color, varies from seven thousand to ten thousand ounces per annum.

The Editor has to express his obligations to Mr. GEORGE BLAIR of Glasgow for his valuable aid during the compilation of this article.

GUMS. — *Gommes*, French; *Pflanzenschleimen*, *Gummi*, German; *Gummi*, Latin.—Under the term gum, says BRANDE, are included several modifications of a distinct proximate principle of vegetals, which are of extremely common and almost universal occurrence. To some of these, the term *mucilage* is occasionally applied.

They are characterised by forming a viscid, mucilaginous, or adhesive solution with water, and by insolubility in alcohol, so that the addition of the latter to a moderately strong aqueous solution of gum occasions the separation of a white precipitate or magma. Another characteristic of gum is its convertibility into mucic or saclactic acid by the action of nitric acid.—*Brande.*

Gum is found upon the bark of certain trees as an exudation, which gradually concretes in transparent or translucent amorphous drops. It may also be detected, in greater or less quantity, in the juices of most plants and fruits.

The several species of gums are distinguished by their behavior with water. Some dissolve in that liquid, and form *mucilages*, as gum-arabic; while others soften and intumesce, as tragacanth. But there is also an intermediate kind, represented by cherry-tree gum, which is only partially dissolved in water. These different classifications of gums have been denominated *arabin*, *tragacanthin*, and *cerasin*—from the Latin *cerasus*, a cherry-tree.

GUM-ARABIC—*Gomme Arabique*, French; *Arabischegummi*, German; *Gummi Acaciæ*, Latin—is the produce of the *Acacia Vera Arabica*, and other varieties. Many have supposed the *shittah* tree, mentioned in many parts of the Old Testament, especially in connection with the building of the tabernacle, to have been an acacia; some have regarded it as the *A. Vera*, while others have thought it to have been the *A. Horrida*.

Dr. ADAM CLARKE, in his comment on Exodus xxv. 5, says:—The Acacia Nilotica, or A. Arabica, is known to have been plentiful in Egypt, and it abounds in Arabia Deserta, the very place in which MOSES was when he built the tabernacle; and hence it is reasonable to suppose that he built it of that wood, which was every way proper for his purpose, being solid, light, and very beautiful.

HIPPOCRATES mentions *Egyptian acacia*, and the *white acacia*, by which, it is supposed, he meant the acacia vera. DIERBACH, however, thinks that the Acacia Senegal is referred to, from the fact that the wood, bark, and flowers of the latter are white. Gum is also named by HIPPOCRATES as being employed in medicine.

PRODUCTION.—The gum of the acacia trees flows in the liquid state, from the trunk and branches, and hardens by exposure to the air. It usually exudes spontaneously, but, in some instances, the discharge is facilitated by incisions. In Barbary, the largest quantity of gum is procured during the hot and parching months of July and August. The more sickly the tree appears, the more gum it yields; and the hotter the weather, the more prolific is it. A wet winter and a cool or mild summer are unfavorable to the production of gum. In Senegal the gum begins to flow when the tree first opens its flowers, and it continues during the rainy season till the month of December, when it is collected for the first time. Another gathering of the gum is made in the month of March from incisions in the bark, which the extreme dryness of the atmosphere at that time is said to render necessary.—*Pereira.*

DESCRIPTION. — Gum-arabic occurs in globular pieces or *tears*, which are colorless or light yellow, more or less transparent, inodorous, and somewhat brittle. The following description of the most important varieties of acacia gum, is extracted from PEREIRA'S *Materia Medica:*—

Turkey or *Arabic Gum* is imported from Leghorn, Malta, Trieste, Gibraltar, Smyrna, Alexandria, Constantinople, *et cetera*, and is the produce of the Acacia Vera, and probably of other species, especially A. Arabica. It occurs in rounded tears, or amorphous or angular fragments, varying from the size of a pea to that of a walnut, or even still larger; some of the pieces being transparent, others more or less opaque, from innumerable cracks extending through them. It has a glassy lustre, is white, yellow, or sherry colored, and has no odor, or, if any, an acid one. Its specific gravity varies from 1·316 to 1·482. It is entirely soluble in water, the solution having the property of reddening litmus, and being feebly opalescent. The latter characteristic is said by GUERIN to be owing to the presence of a small quantity of insoluble nitrogenous matter.

Barbary or *Morocco Gum* is imported from Mogadore and Mazagan. It is probably the produce of Acacia Gummifera. Dr. PEREIRA had two varieties of Barbary gum; one in roundish or irregular tears, mixed with many impurities, imperfectly transparent, and of a dull yellowish color, with a faint tint of green. It was not wholly soluble in water. The other kind, called Mogadore gum, is in small, irregular, broken, mostly yellow pieces, which resemble fragments of Turkey gum.

Gum-senegal is imported from St. Louis, St. Mary's, the river Gambia, Senegal, and Bathurst, and is probably obtained from several species of acacia; but especially A. Senegal, A. Vera, A. Serjal, and A. Adansonii, are said to produce it in part. It occurs in larger tears than those of Turkey or Arabic gum, and large air cavities are frequently found in their centres on breaking them. Whitish pieces are occasionally met with, but for the most part they are yellow, reddish-yellow, or brownish-red. More difficulty is experienced in breaking or pulverizing this gum than gum-arabic, and its fracture is more conchoidal. GUIBOURT distinguishes two varieties of this gum: the first, gum-senegal, properly so called, probably the produce of Acacia Senegal; while the second, gum-galam, is yielded by A. Vera. There is but little difference between them, yet the latter has a greater resemblance to Turkey gum than the former. The pieces of gum-galam are more broken, and therefore more brilliant than those of gum-senegal. Those tears or fragments which have on some part of them a yellowish opaque skin or pellicle, constitute the *Gomme pelliculée* of GUIBOURT. The *Marrons de Gomme*, or *Gomme lignirode* of the same pharmacologist, is also found in the Senegal gum of commerce; it consists of yellowish or dark-brownish pieces, which are difficult to break, opaque, and rough. Treated with water, it is only partially dissolved. GUIBOURT states, that in most of the *marrons* he found a large ovoid cell, which had evidently been the habitation of some larvæ, whence he concludes that this substance is the work of an insect.

East India Gum is imported principally from Bombay, and is most likely the produce of various species. Many pieces—yellow East India gum—agree in their physical and chemical characters with Turkey gum, and are probably the produce of Acacia Arabica, or some allied species. Others, however, are larger, red, or brown—brown East India gum—and more difficult to pulverize than Turkey or Arabic gum.

Cape Gum is imported from the Cape of Good Hope; BURCHELL states that it is obtained from a species of acacia, closely resembling A. Vera, and which he denominates A. capensis. Notwithstanding that the last-named authority asserts, that the Cape gum is in no way inferior to that from A. Vera, it is considered by English dealers as a very inferior kind. It is pale yellow, and apparently resembles Mogadore gum mentioned previously, or small fragments of Turkey gum. It is collected by the Caffres.

PROPERTIES AND COMPOSITION.—Gum-arabic dissolves both in cold and hot water. If this solution be allowed to evaporate spontaneously, the gum is left apparently dry, but, in reality, in a hydrated state, retaining about seventeen per cent. of moisture. If heated slightly above 212°, the color of the gum becomes yellow, and it has an acid taste. When distilled destructively, the products are empyreumatic oil, acid water, carbide of hydrogen, carbonic acid, and a charred mass; the latter leaving, upon ignition, about three per cent. of inorganic matter, composed of carbonates of potassa and lime, with minute portions of chloride of potassium, oxide of iron, aluminum, magnesia, and silicic acid.

Gum is thrown down from its aqueous solution by alcohol as a white magma. Tribasic acetate of lead—but not the neutral acetate—occasions a white precipitate, which BERZELIUS denominated *gummide of lead.* A concentrated solution of sesquichloride of iron causes, when dropped into a gummy menstruum, a brownish translucent gelatinization. Silicate of potassa and oxalate of ammonia produce white deposits, the reaction with the latter being caused by the lime present. Caustic potassa, according to BERZELIUS, first causes in strong solutions of gum a coagulum, which gradually liquefies. A solution of borax occasions in that of gum-arabic, a coagulation which dissolves in free acid. Gum, in this instance, gives a reaction similar to that afforded by starch.

On the trituration of powdered acacia gum with a sufficient quantity of sulphuric acid to form a pasty mass, the mixture soon acquires a brown color; and if it is allowed to stand for about twenty-four hours, then liquefied with water, and carbonate of lime added to unite with the acid, the gum which remains dissolved is considerably changed in character and properties. If, on the contrary, sulphuric acid and gum be mixed, the latter is decomposed with evolution of sulphurous acid, and the production of artificial tannin and a scarcely appreciable amount of acetic acid. Upon adding water after this reaction, about thirty per cent. of carbon is deposited. The ebullition of gum with *very attenuated* sulphuric acid, gives rise to the formation of glucose or grape sugar.

Gum is decomposed by nitric acid, and, on the application of heat, nitric oxide is set free, and *mucic acid* deposits as the temperature of the mass becomes reduced. On carrying the decomposition further, malic and oxalic acids may be detected.

According to VAUQUELIN, when a solution of gum is subjected to the action of a stream of chlorine gas, citric acid is formed; but this statement is very questionable. Chlorine is absorbed by powdered gum, causing the latter to soften and become brown. Hydrochloric acid is also absorbed by gum; the latter becomes brown and glutinous; and, on the addition of sulphuric acid to the magma, hydrochloric acid gas is evolved.

Gum has been analysed by BERZELIUS, PROUT, GUERIN, MULDER, and many others. The following are some of the results of the examination of gum-arabic:—

	Centesimally represented.		
	Berzelius.	Prout.	Mulder.
Carbon,	41·906	41·4	45·10
Hydrogen,	6·788	6·5	6·10
Oxygen,	51·306	52·1	48·80
	100·000	100·0	100·00

The analyses of BERZELIUS and PROUT give rise to the formula, $C_{13}\ H_{13}\ O_{12}$. That deduced from the results of MULDER is $C_{12}\ H_{10}\ O_{10}$. But LIEBIG adopts the formula, $C_{12}\ H_{11}\ O_{11}$, and represents it as a hydrate of carbon, C_{12}, 11 HO, and these views are supported by the composition of the compound of gum with oxide of lead, as ascertained by Berzelius :—

			At. weight.	Theory.	Centesimally.
1 Eq. Oxide of lead,..	1 Eq. Lead,....	104	112	39·58	38·25
	1 Eq. Oxygen,..	8			
1 Eq. Gum,	12 Eqs. Carbon,..	72	171	60·42	61·75
	11 Eqs. Hydrogen,	11			
	11 Eqs. Oxygen,..	88			
1 Eq. Gummide of lead,............			283	100·00	100·00

Fine gum-arabic consists almost entirely of *arabin*, the other constituents being the inorganic matter and moisture.

Pure arabin may be obtained by making a clear aqueous solution of gum, and adding alcohol, when the arabin is thrown down. It is an uncrystallizable amorphous solid, devoid of color, taste, or smell; soluble in water, whether cold or hot, but not taken up by ether or oils. It unites with alkalies. According to Guerin, arabin consists of—

	Centesimally.
Carbon,..............................	43·81
Hydrogen,...	6·20
Oxygen,..............................	49·85
Nitrogen,............................	0·14
	100·00

But it is clear that this analysis must be wrong, since gum itself contains no nitrogen, and no substances containing this element are required in the preparation of arabin. According to the same authority, gum-arabic contains 79·4 per cent. of arabin.

Uses.—Gum-arabic is employed in medicine as an emollient and demulcent, but more frequently as a vehicle for the exhibition of other medicines. It is sometimes slowly dissolved in the mouth to allay troublesome cough, and to diminish irritation of the fauces, by diluting the acid secretions, and sheathing the part from the action of the atmosphere. In inflammatory affections of the intestinal tube, as well as of the respiratory and urinary organs, gum is employed as a demulcent and emollient. A solution of gum may be used as a sheathing substance in cases of acrid poisoning; but its efficacy is believed to be owing to mechanical properties merely. In the state of powder, gum is occasionally employed to check hemorrhage from leech bites. As a vehicle for the administration of other medicines, it is used either in powder or mucilage—in the former condition to give bulk to active and heavy powders, as subchloride of mercury, tartrate of antimony and potassa, *et cetera*, and in the preparation of lozenges; in solution, to suspend insoluble powders—as oxide of zinc or musk—in water; or to diffuse oily and resinous substances through aqueous fluids, and to give form and tenacity to pills. Furthermore, adds Pereira, it is exceedingly useful for various other pharmaceutical purposes, although it is now generally superseded by dextrin.

Its property of suspending fine powders or precipitates in solution, has caused its use in the manufacture of inks; and its clamminess when moist, and firmness when dry, have given rise to its application for cementing or pasting paper or other light articles which are not to be exposed to moisture.

Adulteration.—Gum-arabic, says Normandy, is often adulterated with gum-senegal, which has almost the same appearance, and altogether the same qualities as the former; the latter being considerably cheaper those pieces which are small, light-colored, dry, easily broken, and which, in fact, most resemble gum-arabic, are mixed with it, and sold as such.

It is sometimes also mixed with common cherry-tree gum; but this is generally in dark-brown irregular masses, difficult to break, and when thrown into water they swell and separate from the homogeneous mucilage afforded by the genuine gum in gelatinous clots. This is equally effective as a test, whether the gum is or is not pulverized.

Gum-arabic when ground is in the state of a white powder, and is consequently sophisticated with starch and flour, and the gum generally is altogether replaced by gum-senegal, or partly by cherry-tree gum.

Gum-senegal itself is often mixed, both when in tears and when ground, with cherry-tree gum.

The presence of starch and flour may be readily detected by boiling a small quantity of the suspected gum in water, and testing the mucilage, when it has become cold, with iodine, which imparts to starch an intense blue or violet hue.

Purification.—A patent was granted, in the year 1848, to M. H. Picciotto, for two several methods of purifying and decoloring all varieties of gum-arabic. The first of these is as follows :—

A rather strong solution of pure sulphurous acid gas is prepared by one of the ordinary methods, and protected as much as possible from the contact of atmospheric air. In each six to twelve parts of this solution, one part by weight of gum, either in its natural state or in powder, is introduced. When it has dissolved, it will be found that the greater portion of its coloring matter will have been destroyed, or has chemically combined with the sulphurous acid, forming a colorless compound.

The sulphurous acid may be brought into contact with the gum by other methods than the one just described, as by passing a current of the gas into a concentrated solution of gum, or by introducing the gas into a close receiver, surrounded with a refrigerating substance or mixture; in which case, by the action of the cold and the pressure of the gas itself, it will be condensed into a fluid, and in this state may be commingled with a solution of gum.

Various processes may be resorted to for the removal from the solution of gum, of the free acid, or the acid combined with the coloring matter; but the patentee prefers the following :—

Heat is applied to the close vessel containing the menstruum, during which time the portion of gas evolved may pass through a tube into another receiver containing water, and thus be recovered for another operation. The hot mixture is then run off in small portions into a larger and open vessel, containing a slight excess of some salifiable base, which, in its combination with sulphurous acid, will form an insoluble salt. For this purpose, carbonate of baryta is to be preferred, as both the sulphite and sulphate of baryta are insoluble. The combination is aided by agitation, and when the whole of the disengaged carbonic acid gas has been driven off, and the solution has become neutral, it is allowed to rest for some hours —the vessel being covered—so that the coarser parts of the solid matter may be deposited. The neutralization of the acid may also be effected without previously heating the liquid; but then the patentee recommends that it should be heated after the combination has taken place, so that the whole of the carbonic acid, which might retain in solution a small portion of undecomposed carbonate of baryta, may be evolved.

The menstruum is now to be filtered, in order to remove the sulphite of baryta and other insoluble impurities. The filter employed by the patentee is a thin layer of pure gelatinous hydrate of alumina laid on cloth; but the liquid may also be forced through unglazed earthen or stone ware. After the solution has percolated either of these media, it will be found that all ligneous fibre, silicious and earthy matters, and all particles of insoluble gum have been separated and deposited on the vessels and filter employed, and very little color will remain in the depurated solution; but when a very white gum is required, the process of acidulation must be repeated. By evaporating the filtered menstruum, a colorless, tasteless, and pure gum is obtained, the natural properties of which have not been in the least degree altered.

The sulphurous acid gas may be separated from the solution of gum, without neutralizing it by means of a base, by boiling the mixture in a close air-tight vessel, and conducting the evolved gas into a receiver containing water. If required, the bleaching process may be repeated, by introducing a current of pure sulphurous acid gas into the vessel containing the solution, and then removing it by ebullition. When the menstruum has become cool, it will be found that all the impurities originally united with the gum are deposited at the bottom of the vessel, and the pure solution may be drawn off; or the whole contents of the vessel may be emptied into cloth bags, when the fluid portion will percolate.

The second process is given underneath:—

The gum is dissolved in from six to fifteen parts of hot or cold water, and the solution filtered through cloth. A quantity of pure gelatinous hydrate of alumina is then thoroughly incorporated with the menstruum so as to form a thin homogeneous paste, and this being placed on cloth, a pure and greatly decolored liquid of gum will percolate. Instead of making the mixture just described, the simple solution of gum may be passed through a bed of alumina alone, or the latter with other substances; and, more time being allowed for the filtration, the decoloration will be quite as well effected. If a perfectly white gum is required, it will be essential that the process be again repeated; but as the second and third portions of alumina, after being used, contain very little tinctorial matter, they may serve again for the first decoloration of another quantity of gum. When the hydrate of alumina becomes highly tinged, it is washed with hot water on a filter, to separate the gum from it; after which it is edulcorated with a cold limpid solution of chlorine or chloride of calcium, filtered, and then repeatedly subjected to the action of a stream of hot water. By these means, not only its original whiteness and purity, but also its chemical affinity for tinctorial matter, are restored.

STATISTICS.—Gum-arabic is imported either direct from Alexandria, Smyrna, Tripoli, Mogadore, Tangiers, *et cetera;* or second-hand from those places through Gibraltar, Malta, and the Italian ports.

Previously to the year 1842, the duty on gum-arabic *from British colonies* was six shillings per hundredweight; from other parts twelve shillings; but the duty was then fixed at twelve shillings per hundredweight upon all gums, of whatever origin, and this was subsequently reduced to one shilling upon the same quantity. Of twenty-five thousand, two hundred and eighty-nine hundredweight imported in 1839, Tripoli, Barbary, and Morocco furnished four thousand five hundred and eighty-seven; Turkey, four hundred and thirteen; and the Cape of Good Hope, two thousand seven hundred and thirteen, while fifteen thousand four hundred and thirty-one hundredweight were from the East Indies.

The trade in gum-senegal is principally in the hands of the French.

AUSTRALIAN GUM.—In 1848, Dr. HOPFF received a gum, purporting to be from Australia, which consisted of reddish-brown and brownish-yellow pieces, mostly semiglobular, tear-shaped, and moderately transparent, to which the bark was partly adhering. Internally this gum was much cracked. It was not hygroscopic, was easily pulverized, glittered like glass, and furnished a slightly colored powder. Its aqueous solution had no peculiar taste; when diluted to such an extent that it could be filtered, it gave the following reactions:—

Basic acetate of lead caused a brownish turbidity; subnitrate of mercury produced a greyish opalescence; nitrate of mercury gave a similar, but less decisive reaction; chloride of mercury occasioned no change; iodine scarcely tinged the menstruum.—*Pharmaceutical Journal.*

From the above characteristics it will be seen, as Dr. PEREIRA has remarked, that the Australian gum bears more resemblance to that of the cherry-tree than that of the acacia.

GUM-BASSORA, though described by continental pharmacologists, seems to be new, or nearly so, in British commerce. According to Dr. PEREIRA, it occurs in variable-sized pieces, which are whitish or yellowish, and opaque. It appears to belong to the Bassorine class, as when put into water, it swells up, but dissolves only in part. Its origin is unknown.

BRITISH GUM. — *Artificial Gum — Torrefied Starch—Dextrin.*—Under these names a modification of starch is known, which is often prepared in the following manner:—

Well-dried starch is heated to 300° in sheet-iron trays, when it intumesces, giving off vapors and the odor of highly-baked bread, and forming yellowish-brown masses. This, when ground, is employed as a substitute for tragacanth, senegal, and similar gums, in the dressing, stiffening, glazing, sizing, dyeing, printing and finishing calicos, nets, crapes, laces, silks, papers, and all goods of a similar kind.

Starch, when submitted to the above process, is converted into a gummy substance, which, having lost all gelatinous properties, is soluble in either cold or hot water; and iodine, instead of causing a blue color, as with unaltered starch, communicates to it a dingy purple tint.

It possesses the characteristic property of turning the plane of polarization to the right when acting on polarized light, and is consequently sold in Paris under the name of *dextrin.*

British gum or dextrin is now met with in commerce in three distinct forms; namely, as a white, brilliant, and pearly powder; as a sirupy solution; and in the form of exotic gum, in greater or less perfection, either broken into small fragments, or made into rolls of various sizes.

Formerly, it was only produced in the first condition, that of powder; and if some manufacturers have attempted to impart to it the appearance of the product for which it is so much substituted, they may have been induced to do so from the conviction, that the only way to supersede the old plan was by humoring and even deceiving its consumers with the outward appearance of the old product.

It has since been discovered, that many advantages, not primarily expected, are attendant on the communication to dextrin of the form and appearance of natural gum. It is easily dissolved, and makes a clear solution; in the state of powder it possesses the superiority over dextrin of being more readily packed; and over liquid gum, the advantage of not fermenting.

A misapprehension seems to have been entertained, that, taking advantage of the resemblance, the exotic would be adulterated with the artificial product. Fortunately this is impracticable, as the smell and taste of potato oil, which always accompany artificial gum, are sufficient to betray its presence; and thus, if the purchaser suspects fraud, the most ready means for its detection are in his possession, and may be at once applied.

British gum may be prepared by many other processes than the one just described. Besides being procured by torrefaction, it is also obtainable, either by the use of acids, or by means of diastase.

Payen discovered a method which furnishes a whiter and more soluble product than can be obtained by torrefaction. It consists in moistening one thousand parts of *dry* starch—potato-starch is generally used—with very dilute nitric acid, consisting of two parts of the concentrated acid to three hundred of water. The mass is then divided into small blocks, which, when exsiccated in the air, are rubbed down, and exposed in a proper stove to a current of air heated to about 150° or 160°. The powder is ultimately well dried at a temperature not exceeding 230°. When well made, it dissolves in cold or slightly warmed water, with the same facility as gum. The modified starch obtained by this mode has been also called *leiocom.—Brande.*

A patent was granted in May, 1845, to J. F. Pinel, for improvements in the method of treating farinaceous matters for the production of British gum. The *modus operandi* is as follows:—

Half a gallon of nitric and half a pint of hydrochloric acid are mixed with one hundred gallons of spring water, and as much flour or fecula being then added as is sufficient to form a paste, the whole is well worked together, and left for two hours to settle. After the expiration of this time, the paste is carefully removed into buckets properly prepared for allowing the water to drain off. When this has been effected to the required extent, the mass is divided into small lumps, which are placed on shelves in a drying-room, and allowed to remain until fully desiccated. They are then reduced to powder, and placed on the shelves of a stove, the temperature of which is raised, on the first day to 100°; on the second to 150°; and on the third day to 190°. After this process, the powder is allowed to cool, and is then passed through a sieve. It is next placed in an oven, heated to from 300° to 350°, and when thoroughly baked it is ready for use.

The operator can ascertain if the process has been correctly carried out, by mixing a small quantity of the powder with filtered water, in which it should readily dissolve without leaving any sediment.

It will require little discrimination in the reader to see that this process, though there is some slight variation in the quantity and kind of acid, is yet essentially the same process with that of Payen given above.

If the flour or fecula be grey—that is, if it has been badly prepared, and adulterated or damaged—the patentee substitutes half a pint of sulphuric for the hydrochloric acid, by the agency of which, he states, the heterogeneous matters are separated from the good flour.

This patent also extends to the production of the gum in lumps, so as to resemble natural gum both in color and transparency; and for this purpose the powder is mixed, after it has gone through the stove and been sifted, with as much water as will bring it to the consistence of a paste, adding one part of nitric acid to each four hundred parts of water. When well mixed, the paste is spread upon copper dishes, in layers three-fourths of an inch deep, and subjected, in an oven, to a heat of 240° to 300°. As soon as it has become sufficiently hard, it is removed from the oven into the open air, and when cool, is ready for use.

Since the discovery, by Payen and Persoz, of diastase—described at page 71, Vol. I.—another method for the fabrication of artificial gum has been devised.

This process seems to be the most worthy of attention, and by accepting the modifications of M. Emile Thomas, it will be found to give more perfect results than any other. Thomas' improvements with the original method of operation are thus described in the *Bulletin de la Société d'Encouragement:*—

The fecula must be rendered soluble in vats, heated by steam in such a manner that the temperature can be lowered or heightened with ease. The fecula is first mixed with four times its weight of water, previously brought to the temperature of 120°; and, for this purpose, is gradually introduced into the boiler or other vessel containing the hot water. M. Thomas employed double-bottomed copper boilers, capable of containing four hundred gallons, and at one operation, six hundred pounds of fecula, mixed with one thousand two hundred quarts of water were decomposed. The temperature must be kept at about 140°, until the whole mass is converted into starch. Two per cent. by weight of very fine white malt, and the mucilage obtainable from one per cent. of linseed, are then added. The latter imparts tenacity to the gum. If a greater proportion of malt than that just mentioned were employed, the decomposition would, doubtless, be effected more rapidly; but much more glucose would be formed, and the gum would be, to a greater or less extent, colored.

The temperature of the mixture must be maintained at 120° or 140° until all the starch is redissolved, when it should be suddenly elevated to 167°, as nearly as possible, in order to cause the most powerful action of which the diastase is capable. The thorough agitation of the mixture is then requisite, until the decomposition is almost complete; this may be ascertained by the deep blue tint which the mixture acquires, and also by the action of iodine, which will communicate to the dextrin a purple or violet tint.

The operation lasts about an hour and a quarter; fifteen minutes are required for the formation of the paste, the same period for its dissolution, and the remaining time for rendering it soluble.

M. THOMAS prefers this method of forming the paste to adding the malt, as the reagent spreads much more uniformly throughout the mass, and does not subside to the bottom of the vessel.

The liquor must now be removed from the decomposing vats, and left in pans to settle. This may require from six to eighteen hours, according to the external temperature. During this period, a slight fermentation will be perceived, but it must be checked by the addition of one hundred and forty-five grains of alum for each twenty-five gallons of the liquid. It is essential that sufficient time be allowed for subsidence of the menstruum, as by this means two serious evils are avoided—the coloring of the gum during the baking; and a singular phenomenon so often observed in evaporating viscous liquids, namely, their being quite *still*, which, THOMAS states, is caused by the accumulation of a thick crust on the sides of the evaporating vessels.

The liquor, when drawn off after subsiding, is concentrated by raising it *very slowly* to the boiling point, which precaution is indispensable, for the perfect clarification is effected without any foreign agent, by the coagulation of the vegetal albumen contained in the malt and the linseed mucilage, and is best attained by checking the first boiling. The scum which rises while the heat is maintained, must be carefully removed, and if the boiling is too much accelerated, the gum will first become thick, and afterwards will be colored. When a solid pellicle forms on the surface of the sirup, the baking will be completed.

If it be desirable to preserve the gum in a liquid form, the boiling must be stopped when the menstruum has acquired a sufficient density, and it must then be poured into well-closed vessels previously smeared with oil of turpentine, and the surface of the gum should be covered with a thin layer of the same. This method prevents, tolerably well, the fermentation of the fluid gum.

When the dextrin is to be solidified, the boiling sirup is poured into small, shallow tin vessels, placed upon a hot air stove, maintained at a temperature of from 100° to 120°. At the end of twenty-four hours the gum acquires the consistency of jujube paste, and it is then cut up, with a pair of shears, into small oblong pieces, which are rolled out upon a polished surface, with a wooden cylinder; dusted with pulverized artificial gum; and afterwards placed upon wooden frames, where it is allowed to remain drying for three or four days. THOMAS suggests that the gum would be much better desiccated by permitting it to run upon a cylinder heated to 230° or 250°, but he adds that the economy of this method is questionable.

The last-named authority has remarked with reference to British gum prepared by sulphuric acid, that it possesses the disadvantageous property of being deliquescent. This method is, therefore, never employed, as besides this, the products are often colored. He also states that when nitric acid is employed in the preparation of dextrin, *it must be perfectly pure.* Commercial nitric acid, as obtained by the action of oil of vitriol upon nitrate of soda, always contains a small amount of chlorine; and although this element is contained in diminished proportion in the dextrin, it is nevertheless sufficient to considerably lessen the brilliancy of the colors prepared with the dextrin. Several printers upon paper and vegetal tissues have observed this, but have been unable to account for it otherwise than by attributing it to the inferior quality of the gum.

GUM-BUTEA is the produce of the *Butea Frondosa*, a middling-sized tree, common in Bengal and the mountainous portions of India. Dr. PEREIRA found this gum to be identical with a substance he had previously obtained in the warehouse of an old drug firm in London, under the name of *gummi rubrum astringens*. It occurs, according to the last-named authority, in small, elongated tears, which are blackish externally, and have fragments of bark adhering to them. Small fragments examined by transmitted light are ruby-red. It has an astringent taste, and contains from fifteen to twenty-five per cent. of impurities, consisting of wood, bark, small pebbles, and sand. According to SOLLY, the gum, when purified by water, so as to separate the extraneous matters, is composed of—

	Centesimally.
Gum, with gallic acid and other soluble substances,	73·26
Tannic acid,	21·67
Soluble extractive,	5·07
	100·00

It is employed by the natives of North-western India for precipitating their indigo, and in tanning. English tanners, however, object to its use on account of the disagreeable color it communicates to the leather.

CHERRY-TREE GUM, *Gomme de cerisier*, French; *Kirschgummi*, German; *Gummi cerasi*, Latin; which is also procured from the trunks of plum, peach, apricot, and other rosaceous trees, is similar in appearance to the poorer qualities of gum-arabic. By the action of water, in which it is only soluble to a partial extent, it is divisible into two portions, that which is dissolved being *arabin*, while the insoluble matter is *cerasin.*

It has not been analysed, but its composition is probably the same with that of gum-arabic. Cherry-tree gum is not thrown down either by silicate of potassa or by nitrate of mercury. It does not gelatinise with sesquichloride of iron, but a precipitate is produced on the addition of chloride of tin.

It does not seem to have been employed for any purpose whatever in this country. Dr. Pereira has suggested its substitution for gum-tragacanth in medicine.

GUM-KINO.—*Gomme Kino*, French; *Gummi Kino*, German; *Gummi Kino*, Latin. Of this so-called gum there are two varieties, Botany Bay and East Indian kino, the former being the inspissated juice of the *Eucalyptus Resinifera*, or *Iron bark*, a native of Australia and Van Diemen's Land; while the latter kind is the produce of *Pterocarpus Erinaceus* or *P. Marsupium.* According to Gray, when an incision is made in the trunk and branches of the tree, the juice exudes, at first, of an extremely pale-red color, and in a very liquid state; but it soon coagulates, becoming of a deep blood-red hue, and so remarkably brittle, that its collection is attended with some difficulty. East Indian kino, Dr. Pereira remarks, is presumed to be the substance referred to in the British pharmacopœias, as it is always regarded in commerce as *genuine gum-kino.* It is imported in boxes from Bombay or Tellicherry.

Properties.—East Indian kino occurs in small, angular, glistening fragments, the larger of which appear almost black; the smaller being ruddy. When entire, they are opaque, but in thin laminæ are transparent and ruby-red. They are brittle between the fingers, soften in the mouth, adhere to the teeth, tinge the saliva red, and, though inodorous, have a very astringent taste. Kino imparts both to alcohol and to water a deep-red color; the aqueous decoction, on cooling, becomes turbid. In the latter solution, gelatin, tartrate of antimony and potassa, acetate of lead, sesquichloride of iron, and nitrate of silver, produce precipitates.

Botany Bay kino is met with in irregular masses, many of them in the form of tears, somewhat resembling those of cherry-tree gum in outline, and as large as those of gum-senegal. The purer pieces are vitreous, almost black in the mass; but when in small and thin fragments, transparent, and of a beautiful ruby-red. Some of the pieces, however, from the intermixture of wood and other impurities, are dull. When chewed, it sticks to the teeth, and has an astringent taste, but is devoid of odor. Digested in cold water, it swells, becomes soft and gelatinous, and yields a red liquid, which gives an acid reaction with litmus paper, and yields precipitates with lime-water, gelatin, acetate of lead, sesquichloride of iron, and—if a little caustic potassa or ammonia be previously added—with chloride of calcium. Tartrate of antimony and potassa occasions no deposit. Digested in rectified spirit, Botany Bay kino becomes gelatinous, as with water, and affords a similar red solution, in which water causes no subsidence, but which reddens litmus, and deposits a copious precipitate when potassa, ammonia, or lime-water is added.—*Pereira.*

In 1852, Dr. Christison received from a merchant of Moulmein, a specimen of kino produced in that locality, possessing the physical and apparently the chemical properties of the ordinary kino. Though a small quantity of it was once shipped to England, it is yet, as an article of commerce, unknown.

The pharmacologist last named thus describes it:—

This product consists partly of little angular fragments; but there are larger masses which seem to be portions of cylinders, about half an inch in diameter, apparently moulded by collecting the juice in reeds. These have externally a greyish, striated surface, most unlike that of the broken fragments of commercial kino. They are easily frangible, the broken pieces possessing the exact appearance of ordinary kino, except that they are blacker and more glassy by reflected light: and though opaque, by transmitted light, when of very moderate thickness, yet in very thin fragments, they are of a splendid cherry-red color. They are easily reduced to fine powder, which has a dark, dirty, lake tint. Their taste is very slightly bitter, and intensely astringent.

Cold water acts more quickly on this kino than on that of commerce, gradually dissolving a very large proportion of it, forming a deep cherry-red astringent solution, and leaving a residue of greyish flocculent matter, which is soluble to a great extent in boiling water, and which appears to be analogous to the insoluble variety of gum called bassorin. Boiling water dissolves this kino almost entirely, and the menstruum, when cold, continues nearly transparent for at least an hour; it afterwards becomes slightly turbid, and a scanty flocculent precipitate slowly subsides. Both the hot and cold solutions yield, when much diluted, a deep olive-green precipitate with sesquichloride of iron: when the menstruum is concentrated, a dirty-grey precipitate is formed so abundantly, that the whole fluid becomes a thick, pulpy mass. A solution of one part of the kino in twenty-five of boiling water forms, with the iron-test, a magma too thick to flow. Even a solution in seventy-five parts of cold water has a beautiful intense cherry-red color, and forms with sesquichloride of iron, in the course of an hour, a pulp so thick as to flow only sluggishly.

On comparing these characters with a fine specimen of kino of home trade, and also with a sample from the neighborhood of Goomsoor, Dr. Christison found the last two to be identical, with the single exception, that the Goomsoor product is somewhat redder when seen in bulk, and that the Moulmein kino is blacker, more vitreous in lustre, rather more easily soluble in cold water, and with rather less residue; and when the cold solution is diluted to the strength of one in seventy-five, it requires rather more sesquichloride of iron to throw down all its tannin, and, consequently, the precipitate forms with the water a somewhat firmer pulp. This kino dissolves, with only a trace of flaky residue, in rectified spirit, which forms an intense cherry-red tincture of very pure astringent taste. Its physical characters, the action of water, and the properties of the aqueous solution, are enough to prove that the Moulmein kino is identical with the kino of commerce, and, in point of quality, is somewhat superior. There is no doubt, from its taste, and the action of the iron-test, that analysis will prove the presence of a larger proportion of tannin.

It does not absolutely follow, even from the exact coincidences now mentioned, that the Moulmein kino is derived from the same botanical source with the present officinal kino. The latter has been accurately referred, by the separate researches of GIBSON, PEREIRA, and ROYLE, to the *Pterocarpus marsupium* of ROXBURGH. But the *Butea frondosa* also yields a fine kino, which is scarcely distinguishable in chemical properties from the officinal kind.—*Pharmaceutical Journal.*

COMPOSITION.—Gum-kino was first analysed by VAUQUELIN, in whose days the resources of chemistry were very much limited, causing a deviation from the truth in many cases, and occasioning, with regard to all investigations of the period, a great amount of doubt as to their correctness.

The *comparatively simple* tabulation of VAUQUELIN'S results is as under:—

	Centesimally.
Tannic acid and peculiar extractive,	75
Red gum,	24
Insoluble matter,	1
	100

The presence of catechuic acid has subsequently been proved by A. W. BUCHNER.

USES.—For medical purposes only; it is administered in cases of obstinate diarrhœa; it has occasionally been applied to flabby ulcers as a local astringent.

STATISTICS.—Gum-kino is imported from Rangoon and Madagascar into London and Liverpool, in chests and boxes containing each from one to three hundredweight. It varies in value from fifty to seventy shillings per hundredweight. Duty-free.

GUM-KUTEERA bears considerable resemblance to flaky tragacanth, for which it has occasionally been attempted to be substituted. GUIBOURT considered it as identical with gum-bassora, but PEREIRA states that it is very distinct. It is supposed to be produced by the *Sterculia Urens*, a plant of the family *Byttneriacea*, and is unknown in British commerce.

GUM-MEZGNITE, known synonymously as *muckeet*, *mezgneet*, or *musgnit*, has been described by MORFIT, who was led to submit it to a chemical examination, on account of the facility with which it may be obtained in large quantities, and its very probable *prospective* value as an article of commerce.

It is said to be the product of a tree flourishing extensively in the high and dry regions of the plains of Western Texas, New Mexico, and the adjacent Indian territory. It is a spontaneous semifluid exudation, concreting by exposure into tears and lumps of variable size and form. A portion of the sample obtained by Dr. SHUMARD—who first brought it into public notice in 1854—consisted of small irregular pieces and rounded balls about the size of a hazel-nut; semitransparent, and shading in color from a lemon-white to a dark amber. When broken, the fractured surfaces were brilliant, and the gum was easily reduced to a dull white powder. One of the balls was enveloped with an outer pellicle of gum, about one-sixteenth of an inch in thickness. Its specific gravity was 1·5, but MORFIT remarks that this determination may admit of correction upon purer samples than were obtainable.

Its proximate composition was found to be:—

	Centesimally.
Arabin,	84·967
Bassorin,	0·206
Water,	11·640
Inorganic matter,	3·000
Impurities,	0·236
	100·049

Its elementary composition is represented by MORFIT as—

	Centesimally.
Carbon,	44·706
Hydrogen,	6·500
Oxygen,	48·794
	100·000

which approaches very closely to that of gums arabic and senegal, as represented by GUERIN and MULDER. The general appearance of the gum, continues its describer, is similar to that of gum-senegal and the dark inferior qualities of gum-arabic; while in chemical properties it is also allied to them, being insoluble in absolute alcohol, partially soluble in alcohol of the ordinary strength, and readily forming with hot or cold water a very adhesive mucilage. It is, in fine, a true gum, and promises, in its physical and chemical behavior, much of the advantage expected by its discoverer, as an economical substitute for gum-arabic or senegal.

MUCILAGE.—*Mucilage*, French; *Schleim*, German; *Mucilago*, Latin.—Many seeds, roots, *et cetera*, when infused in water heated to 160° or 170°, impart to it a substance, which, when purified by percolation and evaporation, bears considerable resemblance to gum.

QUINCE MUCILAGE.—One part of quince seed, Dr. PEREIRA states, forms, with forty parts of water, a thick mucilage, which yields with acetate and subacetate of lead, protochloride of tin, nitrate of mercury, and sesquichloride of iron, gelatinous coagula or precipitates. Rectified spirit produces at first scarcely any effect; after some time partial concretion occurs. Sulphuric acid communicates a pinkish tint, and causes the separation of a frothy coagulum, which floats on the mixture. Silicate of potassa, infusion of galls, and oxalate of ammonia produce no change in the mucilage. Quince mucilage is distinguished from arabin, by the effect on it of alcohol, silicate of potassa, oxalate of ammonia, and sulphuric acid; from bassorin and cerasin by its solubility, both in cold and hot water; from tragacanthin, by the reactions caused by alcohol, oxalate of ammonia, and sulphate of iron; from *carrageenin*—see carrageen mucilage below—by the effect of silicate of potassa and acetate of lead. From these and other peculiarities, Dr. PEREIRA proposed to call it *cydonin*—derived from the name of the quince-tree, *Cydonia Vulgaris.*

CARRAGEEN MUCILAGE.—The mucilaginous constituent of Carrageen or Irish moss—*chondrus crispus*—termed by some writers vegetal jelly, or vegetal mucilage, was, from its appearing to have peculiar characteristics, designated by Dr. PEREIRA *carrageenin.* Its properties, according to that distinguished pharmacologist, are as follow :—

Carrageenin is soluble in boiling water; the menstruum gives precipitates with subacetate of lead and silicate of potassa, and, if sufficiently concentrated, gelatinizes on cooling. It is distinguished from ordinary gum by its aqueous solution not producing a precipitate on the addition of alcohol; from starch by its not assuming a blue color on the addition of iodine; from animal jelly by tincture of galls producing no precipitate; from pectin by the absence of any reaction with acetate of lead, as also by the formation of no mucic acid on the addition of nitric acid.—*Pereira's Materia Medica.*

LINSEED MUCILAGE is extracted from the seeds of the flax-plant, *Linum Usitatissimum*, by the agency of hot water. Alcohol causes the formation in it of white mucilaginous flocks. It is also precipitated by protochloride of tin, and by acetate and subacetate of lead. It possesses an acid reaction, and is not changed by chlorine or iodine. On evaporation, a substance similar in appearance to gum-arabic is obtained, which, when digested in water, intumesces, and partially dissolves.

There are many other mucilages, but as they possess characters in common with those described, a notice of them would be unwarrantable.

GUM-TRAGACANTH, or *Gum-dragon*—*Gomme tragaçante*, French; *Gummi tragant*, German; *Gummi tragacantha*, Latin—is a natural exudation from different varieties of the *Astragalus*, or milk-vetch. OLIVIER states that the tragacanth of Asia Minor, Armenia, and northern Persia, is yielded by the *A. Verus.* Mr. BRANT, English consul at Erzeroum, forwarded to Dr. LINDLEY a specimen of *A. Gummifer*, which was stated to be the tragacanth plant of Koordistan, and producing the white or best kind of gum. It was accompanied with a plant of *A. Strobiliferus*, which was said by the same authority to be the shrub from which the red or inferior species of tragacanth is produced.

According to TOURNEFORT, the *Astragalus Creticus* also yields the gum.

DESCRIPTION.—Gum-tragacanth is white, yellowish, or yellowish-brown, and occurs either in moderately large, broad, thin pieces, marked with arched or concentric elevations—*flaky tragacanth*,—or in small, twisted, filiform, spiral fragments—*vermiform tragacanth.* The former is the kind usually found in this country, while the latter is common on the Continent.

COLLECTION AND ASSORTMENT.—According to S. H. MALTASS, the following is the manner in which gum-tragacanth is collected:—In July and August the peasants clear away the earth from the lower part of the shrub, and make several longitudinal incisions in the bark; the gum exudes the whole length of the incision, and dries in flakes; three or four days are sufficient for this purpose, and the product is then collected. In some places the peasants also puncture the bark with the point of the knife. If the weather be hot and dry, the gum is white and clean; but if the atmosphere be damp, and the temperature but moderate, a longer time is required for inspissation, and the gum assumes a yellow or brownish tinge. High winds are favorable for drying, but they cause the contamination of the gum with earthy and silicious matters. While engaged in this labor, the peasants pick off from the shrubs the gum which exudes naturally, and this constitutes the variety known in Britain as *common* or *sorts*. The whole of the tragacanth gathered is mixed and sold to native merchants, who send it to Smyrna for re-sale, in bags containing about two hundredweight each. In this state it is termed *rough* gum, and contains as follows :—

	Per Cent.
Flaky or leaf gum, perfectly white, ...	40 to 50
Flaky or leaf gum, discolored or brown,	15 to 25
Vermicelli gum, ...	10 to 15
Common or sorts, ...	35 to 10

The finest parcels, continues this authority, contain the most *vermicelli*, which is nothing more than the siftings of the *leaf* gum which is broken by carriage from the interior, and by removing from one place to another, together with the small vermicular masses termed *Sesame seed*, which are collected with the leaf gum.

When gum-tragacanth is purchased for shipment to Europe, it undergoes the following assortment:—The large, white, flaky, or leaf gum, termed *French quality*, is first picked out, and the residue is sifted. The coarser portion is returned to the pickers, who remove the *discolored leaf*, which is termed *English quality*. The remainder is then examined, and any stones, or dirty, very black pieces are thrown aside as refuse; the rest, composed of naturally exuded gum and brown leaf, is denominated common or sorts.

The head-man or master-picker then subjects the gum which passed through the first sieve, to the action of a second and finer one, occasionally throwing out any straw or other light extraneous substance which may rest at the top. The gum remaining after this second sifting is given to the women to assort at their own houses. The *white* is separated from the *brown*, and the latter from the *common*. The first is mixed with the French, the second with the English quality.

A third, and still finer sifting now takes place. The gum which passes through is termed Sesame seed; the coarse, which remains upon the sieve, is vermicelli. Both qualities are carefully picked by women. When cleaned, the Sesame seed is again sifted, and the dust and minute particles are added to the sorts or common gum. The Vermicelli and Sesame seed are then commingled, forming the vermicelli tragacanth of commerce.

When the gums are intended for the French market, the fine white leaf only is shipped; the vermicelli is sold for Trieste, and the discolored leaf and sorts for England.

If, however, the whole parcel be worked for Britain, and be required *good*, the French and English qualities are mixed, and the brown leaf which had been left in the sorts is also picked out and added. This procedure reduces the value of the common or sorts.

The various siftings and pickings to which gum-tragacanth is subjected at Smyrna, may be thus tabulated :—

- Rough gum-tragacanth as purchased from the peasants.
  - Bold white leaf gum — *French quality* is picked out.
  - Residue is sifted through a coarse sieve,..
    - *Common* or *sorts* and *discolored leaf* remains.
      - Slightly discolored leaf, termed *English quality.*
      - *Common* or sorts.
      - Refuse.
    - Residue is sifted,
      - Small white to be mixed with French quality.
      - Small brown to be mixed with English quality.
      - Common or sorts.
        - *Sesame*—is sifted.
          - Dust added to sorts.
          - *Sesame.*
        - Vermicelli—remains on sieve,................ Vermicelli gum of commerce.
        - Refuse.
      - Residue is sifted.

—*Pharmaceutical Journal.*

Properties and Composition.—Gum-tragacanth is the type of the *Bassorin* class of gums. It is destitute both of taste and odor. Its toughness is so great as to prevent its pulverization until it has been exsiccated at 212°, when it becomes tolerably brittle. Instead of dissolving in water like gum-arabic, it intumesces, forming a mucilaginous magma. On subjecting this to ebullition with water, it gradually acquires the appearance of a solution of gum-arabic, in consequence, Brande supposes, of its transmutation into arabin.

The soluble portion of gum-tragacanth—tragacanthin or adragantin—is generally regarded as identical with gum-arabic, but differs from it in being unchanged by sesquichloride of iron, or silicate of potassa, and also by the flocculency of the precipitate occasioned by alcohol. Subacetate of lead, protochloride of tin, and protonitrate of mercury, produce deposits similar to those caused in a solution of gum-arabic. The presence of lime is shown by the subsidence occasioned by oxalate of ammonia.

The insoluble part of gum-tragacanth—*bassorin*—is similar to that of gum-bassora. Starch globules may be seen in it, with the aid of a good microscope, and the blue coloration produced in it by iodine is a proof of the presence in it of that principle.

De Candolle has suggested that the intumescence of tragacanth may be caused by the gummy matter being enclosed in cells.

Guibourt states that neither arabin nor bassorin are present in gum-tragacanth, but that it is composed of an organised gelatiniform matter, very diverse, both chemically and physically, from gum-arabic, and which swells and divides in water, so as partially to traverse a filter. The same chemist considers the insoluble portion of tragacanth to be a compound of starch and lignin, and to have, in no respect, the same properties with bassorin.

Guerin-Varry estimated the proximate principles of tragacanth as under :—

	Centesimally.
Tragacanthin or arabin,........................	53·3
Bassorin and starch,...........................	33·1
Water,..	11·1
Inorganic matter,..............................	2·5
	100·0

The ultimate constituents of gum-tragacanth have been determined by Hermann, and by Guerin-Varry :—

	At. weight.	Centesimally represented. Theory.	Hermann.
10 Eqs. Carbon,........	60	40·00	40·50
10 Eqs. Hydrogen,......	10	6·66	6·61
10 Eqs. Oxygen,........	80	53·34	52·89
1 Eq. Gum-tragacanth,	150	100·00	100·00

Guerin-Varry's results are as follow :—

	Centesimally. Soluble part.	Insoluble part.
Carbon,.................	42·01	35·79
Hydrogen,..............	6·42	7·11
Oxygen,.................	54·47	57·10
	102·90	100·00

Uses.—Gum-tragacanth is occasionally employed in medicine as a sheathing or demulcent agent in irritation of the mucous membranes; and also as a vehicle for the administration of active and heavy medicines.

Shoemakers use the inferior varieties, in the form of mucilage, for imparting a gloss to the heels of boots.

Adulteration.—According to S. H. Maltass, gum-tragacanth is adulterated with two inferior gums. These, he says, are collected in Armenia and Caramania from various trees, principally wild almond and plum. That from the former locality is sent to Constantinople from Moussul, whence it takes the name of *Moussouli.* The Caramanian product is sent direct to Smyrna, and is termed *Caraman.*

Both these gums, continues he, are almost worthless, but fetch high prices for the purpose of mixing with gum-tragacanth. By some they are considered to be an inferior kind of the same gum. As neither Caramania nor Moussul gum occurs in flat pieces like tragacanth, and as they are of a dark color—particularly the former—they would be easily detected if mixed with leaf gum without previous preparation. The Jews, therefore, who adulterate all the drugs of Turkey, have found means of deceiving the eye by breaking up the spurious article into small irregular pieces, which are then coated with *white-lead.* The leaf gum is sophisticated with this at the rate of fifty per cent. For mixing with the Vermicelli gum, the adulterant is broken into smaller fragments, and added only to the extent of twenty-five to thirty per cent. The pieces are left largest for the sorts or common gum, which often receives even a hundred per cent. of this vile trash.—*Pharmaceutical Journal.*

When pulverized, gum-tragacanth is very often mixed with a multitude of other cheaper powders, more especially with gum-senegal.

A mixture of gums tragacanth and senegal always forms with water a thinner mucilage than the same quantity of either of them alone. The following process is indicated by PLANCHE for the detection of this fraud:—Make a mucilage of the suspected gum, and add to it a few drops of alcoholic tincture of guaiacum, taking care to agitate the menstruum all the while. If the gum under examination contain any gum-arabic, the mixture, in the course of a few minutes, assumes a fine blue color, whilst if the gum-tragacanth be pure, the tint is unaltered. One-twentieth of gum-arabic can thus be detected. It should be remarked, that only four or five drops of tincture of guaiacum should be employed for two drachms of mucilage, and that when the quantity of gum-arabic is very small, three or four hours must often elapse before the change of color can be observed. When rectified alcohol is poured in a clear and filtered mucilage of gum-tragacanth, it produces only a few flakes, which float in the menstruum, but do not impair its transparency; whilst, if gum-arabic be present, either a precipitate occurs in the liquid, or it becomes opalescent, according to the proportion of gum-arabic which it contains.—*Normandy.*

STATISTICS.—Gum-tragacanth is imported in cases of one hundredweight each into London and Liverpool. Its value, picked, is from ten to fourteen pounds sterling per hundredweight; sorts, from four to eight shillings per pound. Duty-free.—*Poole.*

Subjoined are particulars of the imports and exports of gums—Arabic, Senegal, Kino, and Tragacanth, those being the only gums noticed in the Returns of the Board of Trade—during the years mentioned:—

IMPORTS.

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Gum-arabic,	41,949	46,032	48,484	61,614	40,456	43,960
Gum-senegal,	2,035	2,738	4,267	6,150	3,171	2,164
Gum-kino,	107	435	159	101	3,215	611
Gum-tragacanth,	526	791	1,151	1,390	582	300

EXPORTS.

	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Gum-arabic,	14,425	10,025	12,265	14,559	12,517	20,007
Gum-senegal,	5	—	39	80	93	388
Gum-kino,	118	46	169	93	473	22
Gum-tragacanth,	128	109	167	296	123	131

GUM-RESINS.—*Gommes-résines*, French; *Schleimharze*, German; *Gummi-resinæ*, Latin.—This class of vegetal products has long been recognised in pharmacy, and the various substances forming it certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Their nature is not expressed by the term *gum-resin*, and the designation has consequently been condemned as improper; but it has been long sanctioned by use, and seems likely to be retained. They are the inspissated juices which exude either spontaneously, or by means of incisions, from the stems, branches, and roots of certain plants; and consist of resin, gum, essential oil, with other vegetal substances, as starch, and a small amount of inorganic matter. Their general properties are, that they are solid, most commonly brittle, usually opaque, or at least their translucence is not so great as that of the resins; they have almost always a strong smell, and often an acrid taste. Water partially dissolves them, but the resulting menstruum is opaque, and in general, lacteous. Alcohol takes up a portion of them, forming a transparent solution, which is rendered milky by the addition of water. They are principally used in medicine, having little application in the arts and manufactures.

AMMONIAC.—*Gomme Ammoniaque*, French; *Ammoniak-gummi*, German; *Ammoniacum*, Latin.—This substance is the product of the *Dorema Ammoniacum*, a glaucous green plant, about seven feet high, the stem being about four inches in circumference at the base; a native of Persia. The whole plant, according to PEREIRA, is abundantly pervaded with a milky juice, which exudes upon the slightest puncture being made even at the ends of the leaves. This sap, when hardened, is the commercial ammoniac or ammoniacum of the present day.

The last-named authority states that this term has also been applied to a gum-resin, the produce of the *Ferula Tingitana*, which constitutes the ammoniacum of HIPPOCRATES, DIOSCORIDES, and PLINY. The second of these writers says, that ammoniacum is obtained from a species of Ferula, growing near Cyrene, in Africa. PLINY terms the plant Metopion, and states that it grows in that part of Africa which is subject to Ethiopia, near the temple of JUPITER AMMON, and received its name, as also did the gum-resin which it produced, from a Greek word signifying *sand*, in allusion to the arenaceous nature of the soil of the country. Two kinds of ammoniac are mentioned both by DIOSCORIDES and PLINY; the best resembled olibanum, and had a bitter taste, and an odor like castoreum; the commonest had a resinous appearance, and was commingled with earth and stones. Dr. LINDLEY assured Dr. PEREIRA, that African ammoniac was *certainly the produce of Ferula Tingitana.*

As the Greeks and Romans made no mention of

Persian ammoniac, the product of the Dorema Ammoniacum, they were, probably, unacquainted with it. AVICENNA notices ammoniac, but says nothing of its origin. That of ABU MANSUR MOWAFIK, a Persian physician who wrote about A.D. 1055, and of BEVA BEN KHUAS KHAN, A.D. 1512, was, doubtless, of the Persian kind. The Arabic terms by which the three last-mentioned authors designate ammoniac, resemble the name by which the plant is now known in Persia; hence it may be concluded that they all referred to the same object.—*Pereira.*

DESCRIPTION AND PROPERTIES. — Ammoniac is found in tears and drops, sometimes distinct, but more generally in agglutinated masses. Externally the tears are yellow, with a tinge of brown, with a waxy lustre; internally they are white or cream-colored, and opaque. It is moderately hard, and at ordinary temperatures brittle, but softens like wax with the heat of the hand. It has a faint and somewhat unpleasant, but very peculiar odor, best detected by subjecting it to heat; its taste is bitter and nauseous.

M. PICARD, in 1852, discovered by accident a very characteristic reaction of chloroxide of sodium—usually known as hypochlorite of soda—upon gum-ammoniacum. The addition of a few drops of a solution of the former to an alcoholic menstruum containing ammoniacum dissolved, causes the immediate development of a very distinct coloration. As this chemist was operating at the time with the commercial alkaline salt, which consists not only of chloroxide, but also of chloride of sodium and carbonate of soda, he thought it proper to inquire which of these compounds caused the reaction, and he soon found that it was due wholly to the chloroxide. Another question presented itself:—Is it the resinous or the gummy part of the ammoniacum which acts in this phenomenon? To find an answer to this, he attempted the complete separation of the two principles by the following method:—An alcoholic solution of ammoniacum, evaporated to the consistence of a sirup, was precipitated by distilled water. The resulting resin, well edulcorated, was redissolved in alcohol, evaporated, and reprecipitated. This treatment was repeated until nothing more was removed by tho water, when the resin might be considered as pure. Its alcoholic solution behaved with chloroxide of sodium, like the gum-resin from which it was derived.

The evaporated menstruum obtained in isolating the resin was treated with alcohol, which precipitated the gum, and this manipulation was successively repeated until the gum, which had a brownish cast, dissolved easily and completely in water. This menstruum giving no reaction whatever with the chloroxide, warranted PICARD in asserting that the coloration was due exclusively to the resin. To attain to more precision, he acted on the method prescribed by PELLETIER and BONASTRE for the separation of the resins, which, since their researches, have been termed *resins* and *sub-resins*, according to their solubility in ether; and found that the ethereal solution, which was of a fine amber tint, at once gave the reaction with the alkaline chloroxide; while the small blackish globule of insoluble matter, when affused with ether and dissolved in alcohol, was unaltered by the reagent in question.

The sensibility of the reaction of chloroxide of sodium upon ammoniacum is very intense; a mere trace of the former in a menstruum containing the latter is sufficient to produce the phenomenon. This coloration, however, is not persistent; it disappears in contact with the air. If but little chloroxide has produced the reaction, it will reappear on a further addition; but if the reagent be in excess, the presence of another quantity will not induce a return of tho tint. A large excess of chloroxide causes it to vanish, especially with the addition of an acid which disengages chlorine. To study the reaction satisfactorily, PICARD proposes three questions:—

1. Of all the resins and gum-resins, is ammoniacum the only one which thus comports itself with chloroxide of sodium, so that this reaction would serve as a distinctive characteristic of it?

2. Is this reaction peculiar to the chloroxides, and have the oxidising agents which most nearly resemble them no analogous result?

3. Is it possible by means of this reagent to detect gum ammoniacum in a pharmaceutical preparation, when it is mixed with other substances?

There are so many characters, continues the distinguished French pharmacologist, common to all resins, that gum-ammoniacum could scarcely be expected to possess exclusively the property of being influenced by chloroxide of sodium. If the resin of guaiacum, however, be excepted, which gives with this reagent a bluish-green coloration, none were influenced. The principles furnished by vegetals of the same family offer a remarkable analogy of chemical and therapeutical properties. Galbanum, sagapenum, opoponax, asafœtida, furnished by the *Umbelliferæ*, a natural family from one of the species of which gum-ammoniacum proceeds, have, however, shown no change when treated with chloroxide of sodium. It is the same with myrrh, olibanum, mastic, sandarac, resins of jalap, scammony and elemi, liquid and calamite storax, benzoin, balsam of tolu, dragon's blood, euphorbium, colophony, resin pitch, white pitch, and turpentine. A distinctive characteristic of gum-ammoniacum is, therefore, its property of assuming a red color with chloroxide of sodium. It should, however, be mentioned that these experiments were made with the alcoholic tinctures, *and not with the isolated resins.*

The chloroxides of potassium and calcium have the property, in common with that of sodium, of developing the tint; but chlorine does not possess it. If a little carbonate of soda is previously added to chlorine water, the coloration is readily effected, in consequence of tho formation of a small amount of chloroxide. Chloric, iodic, chromic, nitrous and nitric acids, and sesquichloride of iron, offer nothing remarkable.

In these investigations, the very powerful vinous color communicated to aloes by the alkalies must be borne in mind. Chloroxide of sodium from its alkalinity, reacts in a similar manner.—*The Chemist.*

A specimen of African ammoniac sent from Tangiers in 1839, is thus described by Dr. PEREIRA, to whom it was presented by Dr. LINDLEY:—It is an oblong piece, about three inches long, and one and a half inch thick and broad. Its weight is about eight hundred and thirty grains. Externally it is irregular and uneven, and has a dirty appearance, similar to that which ammoniac would present after repeated handling and long exposure to the air in a dusty situation. It is partially covered with paper. A few pieces of reddish chalky earth, effervescing with acids, are found adhering to it, though the proportion of this on the specimen in question is not sufficient to affect in any way its saleability. It appears to be made up like Persian ammoniac, of agglutinated tears; the internal appearance is also much the same as that of the ordinary gum-resin, except that it is not so white, having a brownish, reddish, and in some places a faint bluish hue. Its odor is very faint, and when it is heated, obviously very distinct from that of Persian ammoniac. Its taste is also much slighter.

COMPOSITION.—Ammoniacum has been analysed by several chemists, with various results. BRACONNOT found it to yield the following:—

	Centesimally.
Resin,	70·0
Gum,	18·4
Gluteniform matter, insoluble in water and alcohol,	4·4
Water,	6·0
Loss,	1·2
	100·0

HAGEN'S analysis gave:—

	Centesimally.
Resin,	68·6
Gum,	19·3
Gluten,	5·4
Extractive,	1·6
Silicious matter,	2·3
Volatile oil and water,	2·8
	100·0

But these statements of the composition of ammoniacum, from the limited means of analysing organic substances at the time they were deduced, are very unsatisfactory; and there is no doubt that an investigation of the subject, now that organic chemistry has become so fully developed, would show their erroneousness. Of the volatile oil of ammoniacum, little, indeed nothing, is known; Dr. PEREIRA giving as a description of it, the simple statement that *it is transparent and lighter than water.*

JOHNSTON obtained the resin of ammoniacum by digesting the gum-resin in alcohol, whereby he obtained a pale yellow solution, which, on evaporation at 150°, gave a transparent, nearly colorless resin, having the characteristic odor of the natural product. This resin is soluble in alcohol and the alkalies; partially so in ether, and in fixed and volatile oils. Heated to 212° for some time, it assumes a yellow color, which gradually deepens, while at the same time the peculiar odor becomes less intense. It is easily fusible, and decomposes at a continued heat of 270°; the volatile matter which is evolved containing more oxygen in proportion to the hydrogen than exists in the resin itself. JOHNSTON has expressed its composition, after slow but complete desiccation, by the formula, $C_{40} H_{25} O_9$.

USES.—Ammoniacum is principally employed in medicine; internally, its chief, almost sole use, is in chronic pulmonary affections, and even in these cases, it is unsuitable if there be irritation or inflammation of the bronchial membrane. Externally, it is applied in the form of plaster to glandular enlargements and indolent affections of the joints, as a discutient or resolvent. —*Pereira.*

Its only use in the arts, says URE, is in the formation of a cement for joining broken china and glass, and which is prepared as follows:—Take isinglass, one ounce; distilled water, six ounces; boil these together down to three ounces; add half that quantity of strong alcohol; seethe the mixture for two or three minutes, and then strain it; next add, while hot, first, half an ounce of milky emulsion of ammoniacum, and then five drachms of an alcoholic solution of resin mastic. This resembles an article sold as *diamond cement.*

ASAFŒTIDA—*Assa fetida*, French; *Asafœtida*, *Teufelsdreck*, German; *Asafœtida*, Latin—is obtained from the *Ferula Asafœtida*, an umbelliferous plant found in Afghanistan, Saristan, and the Punjaub. The footstalks of the leaves, and the fibres of the root, being previously removed, incisions are made in the latter, and the gum-resin then exudes, and is removed. This procedure commences about the middle of April, and is repeated towards the latter end of May, and the beginning of June and July in each year.

According to Dr. PEREIRA, the root of the *Ferula Asafœtida* is perennial, tapering, ponderous, increasing to the size of a man's arm or leg, covered with a blackish-colored bark, and beset near the top with many strong rigid fibres; its internal substance is white, fleshy, abounding with a thick milky juice, which has an excessively strong, fetid, alliaceous odor. The stem is two or three yards high, six or seven inches in circumference at the base, and smooth. The radical leaves attain the length of nearly two feet, and have been compared by KÆMPFER as resembling in shape those of the pæony, but in color and other respects those of common lovage. The fruit is flat, thin, reddish-brown, like that of parsnip, but rather larger and darker.

This is now considered, continues the last-named authority, to be the genuine asafœtida plant; but there is reason to believe that a gum-resin like asafœtida has been procured from other species of ferula. *Ferula Persica* has been described by Dr. POPE as the true asafœtida plant, and the Edinburgh College of Physicians admitted it as being probably one source of the gum-resin. That it really does yield asafœtida seems likely, moreover, from the strong odor of the drug which pervades the entire plant.—*Pereira.*

HISTORICAL NOTICE.—For the historical notice of asafœtida, the Editor is also indebted to Dr. PEREIRA, who has collected from many sources the following:—It is uncertain at what period asafœtida was first known or described. The difficulty in determining its history arises from the confusion which has existed with respect to the *Succus Cyrenaicus* and asafœtida. By many writers the two substances were considered to be identical; but this opinion seems now to have been satisfactorily disproved by the discovery of the plant which yields the Cyrenaic juice, and which agrees tolerably well with the rude figures struck on the Cyrenian coins. It would appear, however, that the Cyrenaic juice becoming scarce, the ancients employed some other substance of similar, though inferior, properties as a substitute, and to both of these they applied the term *laser*. For many years, says PLINY, this plant has not been found in Cyrenaica, because the publicans—or farmers of the taxes—who rent the pastures, finding it more profitable, destroy it as food for cattle. One stalk only, found in these days, was sent to the Emperor NERO. It may be known when cattle meet with young shoots of it, by the sleeping of the sheep, and the sneezing of the goats, when they have eaten of it. For a long time past the only laser brought is that which is produced abundantly in Persia, Media, and America, but it is far inferior to the Cyrenaic. It is not at all improbable, continues Dr. PEREIRA, that the laser of Persia may have been the asafœtida of the present day. MURRAY says the word *asafœtida* seems to have been introduced by the monks into the school of Salernum. But it appears to have been of oriental origin, and may be, as some have suspected, derived from the word laser. There are two kinds of *assa*, says AVICENNA, one *fetid*, the other *odoriferous*.—*Materia Medica.*

DESCRIPTION.—Asafœtida is found in irregular yellowish or pinkish-brown fragments, of different sizes. The newly-fractured surface is whitish or cream-colored, semi-transparent, and possesses a waxy lustre; but on being subjected for a few hours to the combined influence of air and light, it becomes violet-red, and after the lapse of some days, yellowish or pinkish-brown. Dr. PEREIRA has described three varieties:—

1. Asafœtida *in the tear*, which occurs in distinct, roundish, flattened, or oval drops, and also in irregular pieces, varying from the size of a pea to that of a walnut, of a yellow or brownish-yellow externally, but white internally. It is not at all improbable that this variety is obtained from a source different from that whence the lump asafœtida is procured; for its color, externally, is more yellow, its odor is much feebler, and its freshly-fractured surface becomes more slowly and less intensely red by exposure to the atmosphere. As it has considerable resemblance to *ammoniacum in the tear*—with which, indeed, except by its odor, it might readily be confounded—may it not be the substance which OLIVIER calls ammoniacum, and which, he says, is produced by *Ferula Persica?*

2. *Lump asafœtida*, which is the variety usually found in the shops. It occurs in variable-sized masses, of irregular forms, and having a reddish or brownish-yellow tinge. Frequently these masses are observed to be made up of tears, agglutinated by a reddish-brown substance; these form that kind of asafœtida sometimes designated *amygdaloid*.

3. *Stony asafœtida*. Dr. PEREIRA never met with this in English commerce, but has described samples which he received from Dr. MARTINY: It occurs in irregular, more or less angular, pieces, which have the odor of asafœtida, and a yellowish-brown color, and present numerous small shining points or plates. It slightly effervesces in hydrochloric acid. By incineration it yields a white ash, which strongly effervesces on the addition of acids. ANGELINI found in stony asafœtida 51·9 per cent. of sulphate of lime.—*Dr. Pereira.*

PROPERTIES AND COMPOSITION.—Asafœtida is very easily known by its peculiar alliaceous odor. This is the more readily appreciable when the gum-resin is subjected to heat. Exposed to light and air, its recently broken surface soon acquires a red color, which gradually passes into yellowish or pinkish-brown. Its taste is acrid and bitter. With sulphuric acid and heat it blackens; a dark, blood-red fluid is produced, and sulphurous acid is evolved. On diluting the menstruum, and adding an excess of caustic potassa, a beautiful blue color may be seen by reflected light, more especially on the surface.

Asafœtida consists principally of resin, gum, and volatile oil. BRANDES analysed it with the following results:—

	Centesimally.
Resin,	48·5
Gum, with traces of saline matters,	19·0
Bassorin,	6·4
Volatile oil,	4·5
Extractive, with saline matters,	1·4
Sulphate and carbonate of lime,	9·3
Oxide of iron and alumina,	0·4
Sand and lignin,	4·5
Water,	6·0
	100·0

The volatile oil of asafœtida is prepared by distillation, either with water or alcohol, and passes over colorless, though by a brief exposure to the atmosphere it becomes yellow. It possesses first a mild, and subsequently a bitter taste; its odor is remarkably powerful, and as it is very volatile, the atmosphere of any apartment where it may be exposed is soon impregnated with it. It is very soluble in alcohol and ether, but two thousand times its weight of water are required to dissolve it. It contains sulphur, which may be known by its blackening silver, and Dr. PEREIRA thinks it probable that phosphorus is likewise present. According to some, the oil is composed of two sulphides of the hydrocarbon, $C_{12}\ H_{11}$, and when freshly distilled, like the essential oils of black mustard and horse-radish, it contains no oxygen. It acquires an acid reaction from continued contact with the air, and on boiling it, sulphide of hydrogen is disengaged.

The resinous matter of asafœtida may be isolated by digesting the gum-resin in alcohol, and evaporating the solution; by this simple process, however, it cannot be considered as pure, and it is better obtained in this state by adopting the method described by M. PICARD for the preparation of the resin of ammoniacum, and given at page 321. It is soluble in alcohol, oil of turpentine, and oil of almonds. It has the characteristic odor of the gum-resin, and the property which the natural product possesses of becoming violet-red by exposure to the sun's rays. BRANDES states that ether divides it into two portions, resin and sub-resin, which he has described; but JOHNSTON affirms that it is *readily and completely soluble in ether*. Like many other resins, it must be heated for a length of time before it becomes hard and brittle, and reaches its normal condition.

By this prolonged heating, it acquires a darker and brownish color, and is easily decomposed if the heat be carried much beyond 212°. As the temperature rises, the resin froths up very much for some time, giving off a strong alliaceous odor; it then flows quietly till the heat is again increased.

Its elementary composition, according to JOHNSTON, is represented by the formula, $C_{40}\ H_{26}\ O_{10}$, which differs from that of the resin of ammoniacum in containing the elements of an additional equivalent of water.

USES.—In Europe solely as a medical agent; it is found highly useful in spasmodic or convulsive diseases not dependent on the nervous centres; as a stimulating expectorant and antispasmodic in chronic catarrh; in affections of the alimentary canal; as an emmenagogue in uterine obstructions. In some oriental nations, as mentioned in the historical notice of asafœtida, it is employed as a condiment.

BDELLIUM.—By this term two gum-resins are understood; one, obtained from *Amyris Commiphera*, the bdellium of Holy Writ, known as *Indian bdellium*, or *false myrrh;* the other, derived from *Heudolatia Africana*, is called *African bdellium.* It is called by the natives, *niottout.* It occurs in commerce in translucent tears, often of considerable size. These vary in tint, some of them being of a brown color, more or less dark. By age they become opaque, and covered with a white or yellowish dust. Their fracture is dull and ceriferous. Bdellium has a feeble, peculiar odor, and a bitter taste. PELLETIER states that it consists of—

	Centesimally.
Resin,	59·0
Soluble gum,	9·2
Bassorin,	30·6
Volatile oil and loss,	1·2
	100·0

JOHNSTON represents the composition of the *resin* of bdellium, by the formula $C_{40}\ H_{31}\ O_5$, or $C_{80}\ H_{62}\ O_{10}$.

EUPHORBIUM is the produce of different species of *euphorbia*, a plant growing in the interior of Africa. It exudes in the form of a milky juice, so acrid as to excoriate the fingers, and which hardens by the heat of the sun into irregular yellowish tears. It is nearly inodorous, but its dust excites incessant sneezing. Its taste, at first slight, is afterwards acrimonious and burning; when swallowed, it produces vomiting and purging, and acts as an acrid poison; the persons who grind it suffer from headache and giddiness, and often from delirium. It principally consists of resin and a waxy matter, and a considerable quantity of malate of lime is also present. ROSÉ, in his researches, found euphorbium to contain two distinct resins: one, easily soluble in cold, the other, only soluble in hot alcohol, and, under certain circumstances, susceptible of crystallization. JOHNSTON has also examined these resins, but there is some doubt as to the results of the analysis. ROSÉ assigns the formula $C_{40}\ H_{35}\ O_4$, to the crystallizable resin. Euphorbium has also been examined by BUCHNER and HERBERGER, who regard one of the resins as basic, the other acid.

GALBANUM.—Much uncertainty exists with regard to the plant whence this gum-resin is derived. The Dublin College of Physicians have described galbanum, on the authority of LINDLEY, as the exudation of the *Opöidia Galbanifera.* DON found an umbelliferous fruit in the galbanum of commerce, which he believed to be that of the plant yielding the gum-resin; and, as it constituted a new genus, he called it *Galbanum Officinale.* But though it is not at all improbable, says Dr. PEREIRA, that these fruits are the produce of the galbanum plant, yet no proof of this has been hitherto adduced, and Dr. LINDLEY, therefore, very properly asks, *Did the fruit found upon the gum really belong to it?*

It has not yet been precisely ascertained where galbanum is produced. DIOSCORIDES says it is obtained in Syria; a statement which is, perhaps, correct, though hitherto no evidence of this has been acquired. It is not improbable that it is also procured in Persia, or even in Arabia, as suggested by Dr. ROYLE. *Opöidia Galbanifera* grows in the province of Khorasan, near Durrood. The German pharmacologists distinguish two varieties—*Galbanum Levanticum* and *Galbanum Persicum.* The names indicate the localities whence they are supposed to be derived.—*Pereira.*

DESCRIPTION.—Galbanum generally occurs in brownish, or dark brownish-yellow, irregular masses of large size, apparently composed of agglutinated tears. Some of these, when broken, appear translucent, and of a bluish, or pearl-white color. Fragments of the stem and other similar impurities often pervade the tears; and, to remove these, the galbanum is generally subjected to fusion and strained.

Another variety of galbanum is known, but it is comparatively rare. It is in distinct, globular, yellowish tears of about the size of a pea, possessing a feebly resinous and yellow fracture.

PROPERTIES AND COMPOSITION.—Galbanum has a hot, acrid, and bitter taste, and a peculiar, balsamic odor. When subjected to cold, it is rendered brittle, and may be easily pulverized.

It has been analyzed by several chemists. PELLETIER'S results are as under:—

	Centesimally.
Resin,	66·86
Gum,	19·28
Volatile oil and loss,	6·34
Ligneous matters and impurities,	7·52
Bimalate of lime,	traces.
	100·00

MEISSNER'S results, appended, seem much more accurate:—

	Centesimally.
Resin,	65·8
Gum,	22·6
Bassorin,	1·8
Volatile oil,	3·4
Bitter matter, with malic acid,	0·2
Vegetal remains,	2·8
Water,	2·0
Loss,	1·4
	100·0

The volatile oil of galbanum is obtained by submitting the gum-resin, with water, to distillation. It is colorless and limpid. Its odor is like that of galbanum and camphor; its taste is hot, afterwards cooling and bitterish. It is soluble in alcohol, ether, and fixed oils.

The resin of galbanum is dark yellowish-brown, transparent, brittle, and tasteless; soluble in alcohol and ether; scarcely so in spirit containing fifty per cent. of water, or in almond oil; very slightly soluble in oil of turpentine, even when aided by heat. It dissolves in sulphuric acid, forming a dark yellowish-brown liquid.

PELLETIER states that galbanum resin has the remarkable property of yielding an indigo-blue oil when heated to from 248° to 266°. JOHNSTON assigns the formula $C_{40} H_{27} O_7$, as representing the composition of the resin.

USES.—Galbanum is principally employed in medicine; it is administered internally in catarrhs, sometimes in amenorrhœa and chronic rheumatism. Externally, it is applied as a mild stimulant, resolvent, or suppurant, in indolent swellings.

GAMBOGE—*Gomme gutte*, French; *Gutti*, German; *Cambogia*, Latin—is, according to GRAHAM, the produce of *Hebradendron Cambogioides*, a native of Ceylon. Gamboge appears to have been first noticed in 1605 by CLUSIUS, who received some of it in 1603 from PETER GARET of Amsterdam. Admiral VAN NECK had brought this from China, and, according to him, its oriental name was *Ghittaiemou.* In Siam it is obtained, says KONIG, by fracturing the branchlets and leaves, when a yellow milky juice exudes, which is collected either upon the leaves of the tree, or in cocoa-nut shells, from which it is transferred to flat earthen vessels, and allowed to inspissate in the atmosphere; it is finally enveloped with leaves. The cylindrical kind of gamboge is resolved into this form by being deposited, while semi-fluid, in joints of the bamboo.

MURRAY states that gamboge is obtained in Ceylon by wounding the bark of the tree, at the time of flowering, with a sharp stone.

DESCRIPTION.—For the delineation of the different varieties of gamboge, the Editor has to resort to the *Materia Medica* of Dr. PEREIRA as the best source of information on the subject. That eminent authority says:—Two kinds of gamboge are described by pharmacological writers—the Siam and the Ceylon. Of these the first only is known in commerce.

1. *Siam Gamboge.*—This is the gamboge of the shops. It is brought to this country sometimes direct from Siam; at other times indirectly by way of Singapore, Penang, or Canton. It presents itself in commerce in three forms:—1, in rolls, or *solid* cylinders; 2, in pipes, or *hollow* cylinders; 3, in cakes or amorphous masses. The first two varieties are known commercially as *pipe* gamboge. The commonest pieces of the above are called *coarse* gamboge.

a. Pipe gamboge consists of cylindrical pieces, varying in size from one to three inches in diameter. Some of them appear to have been formed by rolling; but many of them are striated, from the impression of the bamboo into which the gamboge juice has been run, and, not unfrequently, portions of the stem are still adherent. The gamboge cylinders are sometimes distinct, and covered externally with a dirty greenish-yellow dust; at other times agglutinated, or even folded so as to form masses of varying sizes and shapes. Pipe gamboge occurs in all qualities, the finest and the worst specimens having this form. *Fine gamboge* is brittle and devoid of odor. It has very little taste at first; but, after some time, it causes an acrid sensation in the throat. Its fracture is conchoidal, and the resulting surfaces are opaque reddish-yellow, with a glimmering lustre. It is completely dissolved by the successive action of ether and water. With a sufficient quantity of the latter fluid, it forms a yellow emulsion, the films of which are good microscopic objects for the observation of *active molecules.* The powder of fine gamboge is bright yellow.

Inferior qualities of this gum-resin are harder, more earthy in fracture. The fresh surfaces are brownish or greyish-yellow, frequently with black spots from the intermixture of foreign bodies. Ether and water successively employed do not completely dissolve it. Iodine readily detects starch in the cooled decoction by the green color which it gives rise to.

b. Lump or cake gamboge occurs in masses of several pounds' weight. Its quality is inferior to the finest pipe kind. Internally, fragments of wood, twigs, and air-cells may be observed. In most of its characters it agrees with the inferior qualities of pipe gamboge, and, like these, contains starch.

2. *Ceylon or Cingalese Gamboge.*—Dr. PEREIRA was unacquainted with this kind of gamboge, which is unknown in English commerce. According to Dr. CHRISTISON, it is usually in small, irregular fragments; but, as originally collected, is in flattish round masses—as if moulded in shallow bowls—weighing about a pound or upwards, and it appears to be composed of aggregated irregular tears, with interspaces and cavities, which are lined with a dark pulverulent matter, or with a powder of an earthy appearance. Altogether it seems a very coarse article. It forms, with great ease, an emulsion nowise inferior in smoothness, and very little, if at all, in brightness of tint, to that of the very best pipe gamboge of Siam.

PROPERTIES AND COMPOSITION.—The properties of gamboge have been, to some extent, treated of in the foregoing description. The following are additional reactions:—

Gamboge affords orange-red tinctures with ether and alcohol, which, when dropped on water, yield, on the evaporation of the solvent, thin, bright yellow, opaque films, which readily dissolve in caustic potassa. The resinous portion of gamboge, of which these films are constituted, has been termed by JOHNSTON gambogic acid. The potassa salt, obtained as just noted by the solvent power of the alkali, gives with acids a yellow precipitate of gambogic acid; with acetate of lead, yellow; with sulphate of copper, brown; and with the salts of iron, dark brown deposits.

Should it be necessary, as it sometimes has been in medico-legal cases, to detect the presence of gamboge amongst other vegetal products, as in pills, *et cetera*, the following simple, but sure, course of procedure may be adopted:—

Digest one portion of the suspected substance in alcohol, and another in ether, and subject the tinctures to the above-mentioned tests. Though the yellow resin of New Holland, the produce of the *Xanthorrhœa*

Hastilis, has a similar appearance, yet its chemical reactions with the tests above-mentioned are very different. Should the yellow coloring matter of turmeric, saffron, or rhubarb be taken, at first sight, for that of gamboge, the examination with acids, acetate of lead, sulphate of copper, and salts of iron successively, may be accepted as positive.

Dr. CHRISTISON gives the following as the centesimal composition of gamboge :—

	Siam Gamboge.		
	Pipe	Cake or Lump.	Coarse.
Resin,	72·5	64·7	48·2
Soluble gum,	22·7	20·3	15·2
Woody fibre,	trace	5·3	13·3
Fecula,	——	5·6	14·5
Moisture,	4·8	4·1	8·8
	100·0	100·0	100·0

Ceylon Gamboge.	
Resin,	71·2
Soluble gum,	19·9
Woody fibre,	5·7
Water,	3·2
	100·0

GAMBOGIC ACID.—Syn. Gambodic acid—Resin.—It has a deep orange color, and communicates a yellow tint to ten thousand times its weight of alcohol. It is soluble in this menstruum, and still more so in ether. Water does not take up any of it. When subjected to a heat of about 400° it is partially decomposed, so that while one portion is soluble in alcohol, as the original resin, the other is insoluble. Gamboge resin forms numerous salts. Its composition has been represented by the above chemist as $C_{40}\ H_{22}\ O_9$. The gum of gamboge seems to be identical with arabin, and like it readily dissolves in water.

The fecula found in the inferior kinds of gamboge is probably an adulterant.

To a small extent gamboge is employed as a water-color; but its principal application is in medicine. It is seldom administered *per se*, owing to its tendency to create nausea and vomiting; but, when combined with milder purgatives, it has been found to be a valuable remedy in constipation; in cerebral affections, as apoplexy; in dropsy; and as an anthelmintic. The full dose of it is said to be from ten to fifteen grains. In excessive quantity it acts as an acrid poison. Dr. PEREIRA records that a drachm administered to a human subject, caused horrible vomiting and purging, followed by syncope and death. No effective antidote is known. HAHNEMANN has, indeed, recommended carbonate of potassa as a means of diminishing the violence of the topical action of gamboge.

MYRRH.—*Myrrhe*, French; *Myrrha*, German; *Myrrha*, Latin. This well-known gum-resin is the spontaneous exudation of the *Balsamodendron Myrrha*. It is repeatedly mentioned in the Old Testament, the earliest allusion being in Genesis, from which it appears that 1729 B.C. it was an article of Eastern commerce. It seems to have been made use of by DEMOCRATES. DIOSCORIDES enumerates several varieties of it; one named the *Troglodytica* being the best. According to some ancient writers, this gum-resin received its appellation from MYRRHA, the daughter of CIMFRAS king of Cyprus, who, after committing criminal acts, absconded to Arabia, and was transformed into a tree, which ever afterwards bore her name.

The myrrh tree was not fully known until EHRENBERG, in 1825, returned from his travels with HEMPRICH in Asia and Africa, bringing with him a specimen which has been delineated and depicted by NEES VON ESENBECK.

DESCRIPTION.—Myrrh, says Dr. PEREIRA, is imported from the East Indies in chests containing from one to two hundredweight each. Formerly the finest kind was brought from Turkey, and an inferior one from the East Indies; but, at the present time, nearly the whole comes from India. Sometimes the same chest contains myrrh of all qualities, which is then termed *myrrh in sorts;* but commonly it is imported more or less assorted.

Myrrh of first quality.—Turkey myrrh occurs in pieces of irregular forms and of variable sizes, consisting of tears—either distinct or agglomerated—usually covered with a fine powder or dust. The color varies being pale reddish-yellow, red, or reddish-brown. The pieces are fragile, semi-transparent, with a dull. and in part splintery, fatty kind of fracture. In consequence of imperfect desiccation, the largest and finest pieces often present internally, opaque, whitish, or yellow striæ, or veins, which have been compared by DIOSCORIDES, PLINY, and many others, to the white marks on the nails. The purest, palest, and most odorous pieces are sold as *picked myrrh*.

Myrrh of second quality consists of distinct tears or grains, which are rounded or irregular, and vary in size from that of a pin's head to a peppercorn. none of them in Dr. PEREIRA's specimens being so large as a small pea. They are somewhat shiny, more or less transparent, and vary in color from pale or whitish-yellow to reddish-brown. It consists of tears of myrrh. intermixed with fragments of gum-arabic, and of some resin very like mastic or juniper. Many druggists regard it as merely the siftings of the finest kind, but Dr. PEREIRA does not agree with this opinion.

Myrrh of third quality.—Formerly this was the only kind imported from the East Indies. It occurs in pieces, which are darker-colored than those of the so-called Turkey myrrh, and the average size of which does not exceed that of a walnut. It is often mixed with other matters, particularly with *Indian bdellium*. and with a substance of similar appearance to dark-red colored Senegal gum.—*Pereira*.

PROPERTIES AND COMPOSITION.—The odor of myrrh is peculiar, but balsamic and fragrant; the taste is bitter, aromatic, and somewhat pungent. Water dissolves the gum principally, while alcohol and ether take up the volatile oil and resin. Myrrh is readily dissolved by the alkalies. When it is subjected to the action of nitric acid, a vinous hue is produced. According to PELLETIER it consists of thirty-four per cent. of resin and sixty-six of gum. RUICKHOLDT states that it contains, when of the best quality, between forty-four and forty-five per cent. of resin. BRANDES and BRACONNOT have also analysed it, with the following results:—

	Centesimally represented	
	Brandes.	Braconnot.
Volatile oil,	2·60	2·5
Resin,	27·80	23·0
Gum — Soluble,	54·38	46·0
Gum — Insoluble,	9·32	12·0
Salts—benzoates, malates, phosphates, sulphates, and acetates of potassa and lime,	1·36	—
Impurities,	1·60	16·5
Loss,	2·94	
	100·00	100·0

According to BRANDES, the 27·80 per cent. of resin found by his analysis, consisted of 22·24 *soft*, and 5·56 of *hard* resin, the two soluble in alcohol. The former he distinguishes as odorous, and insoluble in ether. UNVERDORBEN regards it as a compound of hard resin and volatile oil. The hard resin is characterised as inodorous, soluble in the caustic alkalies, but not taken up by ether. The resin prepared by RUICKHOLDT was of a brown color, fused at a temperature below 212°, and slightly retained the taste and odor of the gum-resin. By subjecting it to heat, he obtained a modified resin, which he has termed myrrhic acid.

The volatile oil of myrrh has the odor and taste of myrrh; it is soluble in alcohol, ether, and the fixed oils; it is thin, but has a specific gravity higher than that of water. It is devoid of color, but becomes yellowish by keeping, probably from the absorption of oxygen. It forms red menstrua, with sulphuric, nitric, and hydrochloric acids. When exposed to the atmosphere, partial evaporation occurs, and a glutinous, varnish-like magma remains.

The Editor learns that myrrh is often mixed with Indian bdellium—the produce of the *Amyris commiphora*. *Bdellium*, in appearance and taste, is often very similar to myrrh, but differs in odor, and is characterized by its great amount of bassorin. Besides this, it is often mixed with another substance, for the detection of which BLEY and DIESEL give directions as follows:—

Pseudo-myrrh, which has been frequently found incorporated with the genuine myrrh, consists of large pieces of different forms, the majority of them seeming to be fragments of a cylindrical body; they are coated externally with dust, and have a dirty reddish-brown color; the surface of fracture is tolerably even, of vitreous lustre, brownish-yellow color, and nearly as transparent as Senegal gum. It has a faint myrrh-like odor, and a disagreeable, bitter, somewhat balsamic taste. Nitric acid dissolves it, yielding a bright yellowish liquid, from which water separates small yellowish particles. Genuine myrrh yields with nitric acid a transparent dirty-yellow liquid. *Bdellium indicum* is not dissolved by nitric acid; it softens, becomes whitish and opaque. Bibulous paper, moistened with the alcoholic extract of myrrh, and then with nitric acid, acquires the blood-red color first observed by BONASTRE; bdellium and pseudo-myrrh exhibit only a yellow or brownish coloring. *Bdellium indicum* is, moreover, distinguished by its greenish-brown hue, its more terebinthinate odor, and bitter and somewhat acrid taste. It becomes viscous when held for some time between the fingers. Myrrh yields a bright golden-yellow tincture, and an opaque whitish residue; pseudo-myrrh, a high yellow one, and a semi-transparent residue; *myrrha indica*, a dark-yellow tincture, and an opaque residue. An addition of water produces in the first and last a milky turbidness, and in the second no change. Nitric acid—six drops to twenty of the tincture—yields with *myrrha electa* a yellowish-white opacity, upon which, after a time, the periphery of the liquid acquires a bright violet color, while the centre remains yellow. *Myrrha indica* behaves similarly, only that the tint is darker; pseudo-myrrh does not exhibit this reaction. Fuming nitric acid produces with the tincture of *myrrha electa* an amber-brown, and finally a dark violet color; on evaporation, a dark gamboge-looking residue is left; *myrrha indica* exhibits the same reaction; pseudo-myrrh experiences no change. *Bdellium indicum* and *africanum* are distinguished by their not assuming a violet hue on their treatment with nitric acid. About two grains of myrrh, shaken with an ounce of water and filtered, yield with solutions of salts of the oxide of lead a considerable precipitate. *Bdellium indicum*, treated in the same manner, exhibits scarcely any opacity.

USES.—Like most of the other gum-resins, myrrh is employed only in medicine; it is useful in disordered conditions of the digestive organs; in excessive secretions from the mucous membrane; and, externally, as a dentifrice, and as a gargle for ulceration of the throat in the form of tincture.

OLIBANUM.—*Oliban*, French; *Oelbaumharz*, German; *Olibanum*, Latin. This gum-resin, employed by the ancients in their religious rites under the name of *frankincense*, and first mentioned by MOSES, is derived from the *Boswellia Thurifera*, a terebinthaceous tree, inhabiting the mountainous parts of Coromandel.

DESCRIPTION.—Dr. PEREIRA describes it as consisting of *round*, *oblong* or *ovate*, *pale-yellowish*, *semi-opaque*, *fragile tears*, *having a balsamic resinous odor*. JOHNSTON is of opinion that it is a mixture of two distinct gum-resins. The one he delineates as consisting of opaque, dull, hard, brittle pieces, which, when introduced into alcohol, become almost immediately white and opaque, from a white powdery coating or crust left on their surface as the soluble portion is taken up. This variety constitutes the larger portion of the olibanum of commerce, and is the more fragrant when burned. It contains an acid resin and volatile oil.

The second variety is characterised as being in clearer, more yellow, less brittle, opaque pieces, generally in long tears as they have flowed from the tree, containing less gum than the other kind, and becoming clear and transparent when immersed in alcohol. All the tears of olibanum experimented upon by Dr. PEREIRA became opaque when introduced into alcohol.

COMPOSITION.—Olibanum has been examined by BRACONNOT, who gives the following as its centesimal composition:—

	Per cent.
Resin,	56·0
Gum,	30·0
Volatile oil,	8·0
Matter like gum, insoluble in water and alcohol,	5·2
Loss,	0·8
	100·0

Dr. STENHOUSE, who examined the volatile oil of olibanum, found it to be colorless, and similar to turpentine, but possessed of a more agreeable odor. Its composition is represented by the formula C_{35} H_{28} O.

JOHNSTON has distinguished two distinct resins, produced by both varieties of the gum-resin before-mentioned. The resin from the first of these gave the composition C_{40} H_{32} O_6. That from the second, consisting of the clearer, yellower, elongated tears, resembles colophony, and its formula is C_{40} H_{32} O_4.

USES.—Olibanum is, to a great extent, disused for medical purposes. It was formerly administered in chronic diarrhœa, old catarrhs, and in affections of the chest. It is sometimes employed for fumigation, and enters into the incense employed in the services of the Roman church.

OPOPONAX.—*Opopanax*, French, German, and Latin.—This gum-resin is the inspissated juice of the *Opoponax Chironium*, a plant flourishing in Greece, Italy, Sicily, and in the South of France, and bearing a great similarity to parsnip. It was employed by HIPPOCRATES, and is mentioned both by DIOSCORIDES and by THEOPHRASTUS.

Opoponax occurs in reddish tears and lumps, tasting acrid and bitter, and possessing a mouldy, disagreeable odor. The following is its constituents, as ascertained by PELLETIER :—

	Centesimally.
Resin,	42·0
Gum,	33·4
Lignin,	9·8
Starch,	4·2
Wax,	0·3
Extractive,	1·6
Malic acid,	2·8
Volatile oil, traces of caoutchouc, and loss,	5·9
	100·0

On evaporating the spiritous solution of opoponax, a transparent brown resin, having a peculiar odor, is obtained. It readily fuses at 212°, and, after remaining for a short time at that temperature, becomes brittle upon cooling. It dissolves in alcohol and ether, and in the caustic alkalies. The alkaline solution is reddish, and parts with the resin, on the addition of hydrochloric acid, in yellow flocculi. Its composition, as it exists in the natural gum-resin, is as under :—

		Centesimally.	
	At. weight.	Theory.	Johnston.
40 Eqs. Carbon,	240	63·67	64·01
25 Eqs. Hydrogen,	25	6·63	6·75
14 Eqs. Oxygen,	112	29·70	29·24
1 Eq. Opoponax resin,	377	100·00	100·00

USES.—Opoponax was formerly employed in medicine, but it is now banished from the Materia Medica as enumerated in the British Pharmacopeias. It is adapted to the same cases as the other gum-resins of this class. Dr. PEREIRA is of opinion, that it is more allied to ammoniacum than to any other of these substances.

SAGAPENUM.—*Sagapénum*, French and German; *Sagapenum*, Latin.—Sagapenum is mentioned, says Dr. PEREIRA, by HIPPOCRATES, DIOSCORIDES, and PLINY. The latter calls it *sacopenium*. DIOSCORIDES says it is a liquor obtained from a ferulaceous plant growing in Media. Nothing is known with respect to the plant yielding sagapenum. WILLDENOW considered it to be *Ferula Persica*, and he has been followed by SPRENGEL and others; but there is no evidence to prove that sagapenum is obtained from a *Ferula*, for the statement of DIOSCORIDES cannot be admitted as having much weight.

BRANDES' analysis of sagapenum gave the following results :—

	Centesimally.
Resin,	50·0
Gum, with calcareous salts,	32·5
Volatile oil,	3·5
Bassorin,	4·2
Malate and phosphate of lime,	1·1
Impurities,	4·2
Water,	4·5
	100·0

Sagapenum of the finest kind consists of masses made up of agglutinated, brownish-yellow, semi-transparent tears, resembling galbanum, but having a darker color and a more alliaceous odor. A more common sort occurs in soft, tough masses, in which no distinct tears are to be seen. Its taste is hot and acrid, and, when heated, it evolves a much more aromatic and agreeable odor than galbanum. It is imported from the Levant.

The oil of sagapenum has a mild bitter, alliaceous taste, subsequently becoming hot; its odor is also garlicky. It is of a pale yellow color, dissolves in alcohol and ether, and is reddened by sulphuric acid. Its specific gravity is greater than that of water.

The resin of sagapenum has been examined by JOHNSTON, who gives, as the representative of its composition, the formula C_{40} H_{29} O_9. It possesses a strong garlic odor, and easily fuses, becoming fluid at 212°. Ether resolves it into two resins :—

1. The resin *insoluble in ether* is devoid of taste and odor, and is of a brownish-yellow tint. It is soluble in alcohol and the alkalies, but is not taken up by oils of turpentine and almonds.

2. The resin *soluble in ether* possesses the odor of sagapenum in a slight degree; its taste is mild, subsequently bitter; its color, reddish-yellow. It is soluble in alcohol, and partially so in oils of turpentine and almonds. Sulphuric acid dissolves it, forming a blood-red menstruum, from which a violet-tinged matter is separated by the addition of water.

USES.—The medicinal effects and uses of sagapenum are similar to those of asafœtida,—see page 322. It is now very little employed.

The Editor thinks it most remarkable that so little is really known with respect to the previously-cited compounds. There is now a great field open to young chemists to investigate their nature and true composition, *et cetera*, so as to remove many of the inaccuracies regarding them.

STATISTICS.—The Returns of the Board of Trade for 1850 to 1855 only enumerate Ammoniacum, Asafœtida, Euphorbium, Gamboge, Myrrh, and Olibanum. Annexed are the imports and exports of these for the years 1850, 1851, 1852, 1853, 1854, and 1855:—

IMPORTS.

Years ending 5th January,	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt	Cwt.	Cwt.	Cwt.
Ammoniacum,	832	391	304	60	19	—
Asafœtida,	820	1,922	1,167	2,170	1,555	1,251
Euphorbium,	17	12	14	—	—	99
Gamboge,	561	1,490	701	455	173	259
Myrrh,	545	620	844	282	579	689
Olibanum,	4,539	11,450	8,837	9,029	13,383	10,817

EXPORTS.

Years ending 5th January,	1850.	1851.	1852.	1853.	1854.	1855.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Ammoniacum,	705	222	319	246	168	79
Asafœtida,	507	1,049	1,176	904	731	795
Euphorbium,	—	—	—	—	—	4
Gamboge,	426	153	335	1,056	235	373
Myrrh,	113	263	535	341	272	180
Olibanum,	4,798	11,990	8,739	8,892	12,756	11,757

GUN-COTTON.—*Coton-poudre*, French.—Some years ago this substance created quite a *furore* in the scientific world; but the expense of gun-cotton is considerably higher than that of gunpowder, and this with other drawbacks has been a great obstacle to its being extensively used. Ordinary cotton is one of the almost innumerable forms of lignin, a compound of carbon, oxygen, and hydrogen; but, by subjecting cotton to the action of nitric acid, a new element enters into the composition—namely, nitrogen, which is found in nearly all explosive bodies.

The action of nitric acid on vegetal matter had long attracted the attention of chemists before the discovery of the remarkable detonating compound now under notice. In 1813, BRACONNET gave an account of a new substance obtained by the action of concentrated nitric acid on starch, sawdust, linen, and cotton wool. He named this xyloidin, from the Greek word signifying wood, and described it as being white, pulverulent, neutral, and very inflammable. It is easily formed by boiling starch for a few moments in concentrated nitric acid, until solution takes place; on pouring the resultant into cold water, the xyloidin is precipitated, and may be collected and exsiccated. In 1838, PELOUZE called the attention of the Academy of Sciences to the properties of xyloidin, which he observes is very combustible, taking fire at 365°, burning with great rapidity, and almost without residue. This property led him to an experiment which he thought susceptible of some applications, especially in artillery. By plunging paper in nitric acid, specific gravity 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in two or three minutes, then withdrawing it, and, lastly, washing it in water, a kind of parchment impermeable to moisture, and extremely combustible, is obtained. DUMAS proposed to name the compound *nitramidine*, and mentions the application of paper and pasteboard prepared by nitric acid for fireworks.

At a meeting of the British Association at Southampton, in 1846, it was stated that Professor SCHÖNBEIN had discovered a mode of rendering cotton so detonating as to form an excellent substitute for gunpowder. Soon after this announcement, Professor OTTO of Brunswick published an account of an explosive cotton, as did also MOREL of Paris, and BÖTTGER of Frankfort. SCHÖNBEIN undoubtedly, as DUMAS admits, deserves the honor of having been the first to show that the products of the action of nitric acid upon lignin are superior in explosive energy to gunpowder; but it must be recorded that, as far back as 1832, ROBIQUET produced an insoluble powder, explosive when heated, by the addition of water to a solution of sawdust in strong nitric acid. In April, 1847, SCHÖNBEIN'S patent was enrolled; the specification states, that in preparing the cotton the patentee uses nitric acid of specific gravity 1·45 to 1·50, and sulphuric acid of specific gravity 1·85. These acids are to be mixed in the proportion of three parts of the latter to one of the former; the mixture is allowed to cool down to between 50° and 60°, and then rough cotton, free from all extraneous matter, is immersed in the liquid, in as open a state as possible, in a porcelain vessel. When thoroughly soaked, the excess of acid is to be drawn or poured off, and the cotton squeezed lightly with an earthen presser to separate the principal part of the acid. The cotton is covered over and left for an hour, then pressed, and well washed in running water, to get rid of all free acid; it is next to be partially exsiccated by pressure, and to insure its freedom from acid, it is to be washed in a dilute solution of carbonate of potassa, made by dissolving one ounce of this salt in a gallon of water; it is then put in a press, and the excess of alkaline solution squeezed out, leaving the cotton nearly dry. It is next washed in a solution consisting of one ounce of pure nitrate of potassa in one gallon of water, and when again pressed is dried in a room heated by steam or hot water to the temperature of from 150° to 170°. The saltpetre appears to increase the explosive force of the cotton, but it is not absolutely necessary. Of the cotton thus prepared, three parts are said to be equal in force to eight parts of Tower-proof gunpowder.

A simpler method of preparing gun-cotton in small quantities was proposed by Mr. THOMAS TAYLOR in 1846, which is to mix in any convenient glass vessel an ounce and a half, by measure, of nitric acid—specific gravity 1·45 to 1·50—with an equal quantity of sulphuric acid—specific gravity 1·80. When the mixture has cooled, place one hundred grains of fine cotton wool in a mortar, pour the acid over it, and with a glass rod imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely saturated, remove the acid, and, with the aid of a pestle, quickly squeeze out as much liquid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water or under a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water-bath. Nitric acid of the specific gravity of 1·50 answers better than that of 1·45, the cotton being much less acted upon by the strong acid. Nitric acid of the specific gravity 1·36 converts the cotton into a gelatinous mass.

Gun-cotton is considerably heavier than unprepared cotton, and may be distinguished therefrom by its harshness, and by the crepitating sound produced when pressed by the hand. When well made, there is scarcely any change in color or general appearance. It may also be known from common cotton by its electric condition; for if a portion be pulled briskly between the finger and thumb of a dry hand, the fibres will adhere with great tenacity. If a strip of prepared paper be thus treated, it will, on presenting one end to the knuckle, be alternately attracted and repelled, and thus part with its electricity. Gun-cotton is also perfectly soluble in ether, and if the solution be poured on the surface of cold water, the xyloidin yields an opaque film thereon, which, when collected and dried, forms a remarkably explosive paper.

The detonating character of gun-cotton appears to be due to the formation of xyloidin in the tubes and upon the exterior of the cotton fibre, under the action of the nitric acid. Gun-cotton explodes with very great rapidity at from 350° to 400°. If a little gunpowder be placed on a sheet of writing paper, and a small piece of gun-cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp or candle, the heat will soon be sufficient to ignite the cotton, but the powder will not be kindled; and, although the cotton explodes in contact with the powder, its action is so rapid that there is not time enough to raise the gunpowder to the temperature required for its explosion. This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men that a tardily-exploding material is the best for artillery practice. Thus, when a slow powder is used, the ball acquires a slight degree of motion, which is imparted to the air in front of it, before the full power of the detonation is exerted; and that motion is gradually increased during the remainder of the explosion. But if the action takes place too quickly, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and silver have not been more extensively used in warfare.

When gun-cotton has been carefully prepared, the products of its combustion are carbonic acid, aqueous vapor, and free nitrogen. In some cases nitrous acid is produced, owing to defective washing; and when nitrate of potassa has been employed, or, in fact, a solution of any salts, a dense white vapor accompanies the explosion. The quantity of water produced during the decomposition of the cotton by heat is so great, as to constitute an objection to its use in fire-arms. Its hygrometric condition also impedes its utility; for if a quantity be exposed for an hour or two to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be employed; it cannot be protected from atmospheric moisture by compression into cartridges, as in that state it does not explode with certainty. The idea of using the fulminating cotton as a substitute for gunpowder for artillery purposes, seems to be completely abandoned; but on account of the small quantity of smoke given off, as well as on account of its enormous force, it is much used for mining purposes, the proportionate quantity employed being a fourth of that of powder.—*Tomlinson.*

In the explosion of gun-cotton there appear to be found very decided quantities of nitrous and of hydrocyanic acid. The former corrodes fire-arms, and the latter vitiates the surrounding air in a mine.

The most recent and best information on gun-cotton and its substitution-compounds is given in a paper by Mr. Edward Hadow, from which the following interesting details are transcribed.

Analyses of gun-cotton have been published by Pelouze, Peligot, Gladstone, Porrett, Ransome, and likewise by Schönbein; they exhibit, however, a remarkable want of agreement with each other, both in the formulæ to which they give rise, and in the per-centage increase of weight which they would represent the cotton to have obtained on its transformation into gun-cotton.

Pelouze states that cotton constantly gains from seventy-four to seventy-six per cent., giving the formula $C_{24}\ H_{17}\ O_{17},\ 5\ NO_5$, corresponding to an increase of seventy-five per cent. exactly. Peligot's formula is $C_{12}\ H_9\ O_9,\ 3\ NO_5$, according to which the gain must be 94·4 per cent. Ransome obtained $C_{12}\ H_8\ O_{10},\ 2\ NO$, which represents an increase of 65·4. Dr. Gregory states it to be 69·5, which corresponds with that required by the formula which Gladstone ascribes to the most explosive gun-cotton, $C_{24}\left\{\begin{matrix} H_{15} \\ 5\ NO_4 \end{matrix}\right\}O_{20}$, while the formula of Porrett and Teschemacher, $C_{12}\ H_8\ O_8,\ 4\ NO_5$, would *double* the original weight of the cotton. Schönbein merely gives the per-centage of carbon, nitrogen, hydrogen, and oxygen, from which the lowest formula that can be calculated corresponds nearly to $C_{47}\ H_{31}\ O_{68}\ N_{10}$. In consequence of this disagreement between the formulæ, giving rise to so marked a difference in the per-centage increase of weight deduced from them, it was evident that a careful determination of the weight actually acquired by cotton, after immersion in acids, could alone throw much light on the matter, by pointing out the formula upon which most reliance was to be placed, and from which the composition of the soluble variety might be determined, provided that it were indicated by a definite and constant increase of weight. While ascertaining this point, Hadow was anxious likewise to discover what strength and what proportions of acids were capable of producing the soluble gun-cotton, as well as whether there were more than one such compound; expecting that, if such were the case, there would be always an augmentation of weight closely corresponding to two or more numbers from which formulæ might be calculated, or by which at least the results of analyses might be controlled.

In the preparation of these compounds, nitric acid was not used alone, since a very slight difference in strength produced a great difference in the result. $HO,\ NO_5$ gives an insoluble product, while $HO,\ NO_5 + HO$ destroys the texture of the cotton; and having ascertained that when sulphuric acid is used, no trace of it exists in any of the compounds, a mixture of the two was always used; the latter acid being advantageous for the purpose of increasing the bulk of the mixture, retaining the water abstracted from the cotton, and preventing the solution of the compound, which takes place to a greater or less extent in nitric acid *per se.* The mixtures were likewise made in atomic proportions, that their formulæ might be easily retained in the memory, and similar mixtures be prepared from acids of various strengths. After some trials, those which contained one equivalent of monohydrated nitric acid with two equivalents of monohydrated sulphuric acid, proved to be best; and mixtures being made with the acids in this proportion, and from one to five additional equivalents of water, the fifth was found to disintegrate the cotton. The results obtained from one hundred of cotton were as follow:—

$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}$	$HO = 177$	Insoluble in ether + one-eighth alcohol except the last, which is slightly attacked.
$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}$	$2\ HO = 176$	
$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}$	$3\ HO = 171{\cdot}7$	
$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}$	$4\ HO = 157$	Very soluble.
$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}$	$5\ HO =$ about 140	Soluble in great measure.

The interval between the third and fourth appeared in some degree to correspond to what had been expected. That between the fourth and fifth was doubtful, from the loss of the latter, and from its apparently containing an admixture of unchanged cotton; but on trying fractional additions of water, a corresponding intermediate increase of weight was likewise produced in the cotton: for example,

$$\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}3\tfrac{1}{3}\ HO = 166{\cdot}4\ \left\{\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}3\tfrac{2}{3}\ HO = 160{\cdot}5$$

both compounds proving perfectly soluble. It was likewise found on repeating these experiments, that it was difficult to obtain the same increase of weight unless the mixture corresponded accurately in composition. The cotton in these researches was thoroughly exsiccated in a current of dry air at 212°, and in consequence of its hygroscopic properties, was weighed in the same tube in which the desiccation took place. At first the gun-cottons were likewise carefully dried at low temperatures, after thorough washing in distilled water; but the results not being found quite accurate, and a gradual loss of weight being observed at temperatures below 212°, the drying was effected by placing them *in vacuo* over sulphuric acid for twenty-four hours, after which they were found not to sustain the slightest diminution in weight. The acids were also used in large proportion to the quantity of cotton, that the water abstracted might have no appreciable effect in diluting the mixture; and as a precaution, the immersion was continued for several hours, although the full effect appears to be produced in a very short space of time. It was, however, found that, notwithstanding these advantageous conditions for the production of definite compounds, very variable increments of weight were acquired by the cotton, ranging from about forty per cent. upwards.

Immersion in acids previously warmed was then tried, but as the cotton was found to lose weight in proportion to its duration, owing to a slow solution even at 120°, nothing could be learnt from the weighing of the compound; in other respects, however, the result of the experiment with hot acids proved curious and interesting, from the fact that $\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\}3\ HO$, which at 60° gave rise to an almost insoluble compound, produced at 130° one perfectly soluble in ether $+ \frac{1}{8}$ alcohol: the other acid mixtures, containing *more than* three equivalents of water, produced soluble compounds, both at 60° and 130°, but their solutions differed remarkably in one respect; for all soluble products formed at ordinary temperatures, when dissolved in the proportion of six grains to the ounce, yield thick glutinous solutions, while all those which are the result of acids at the temperature of 130°, give perfectly fluid ones, which produce, on drying, membranes far exceeding the former in strength and toughness, and much better adapted to photographic or surgical purposes. By far the best mixture for producing collodion-wool is that represented by the formula $\left.\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\} + 3{\cdot}5\ HO$, which is obtained by mixing eighty parts by weight of nitric acid, specific gravity $= 1{\cdot}424$, with one hundred parts by weight of sulphuric acid, specific gravity $= 1{\cdot}833$; as—

$$\begin{array}{lcrcl}
\text{Sulphuric acid, specific gravity, 1·833,} \ldots\ldots\ldots\ldots & = & 2\,(HO,\ SO_3 + 0{\cdot}33\ HO) & = & 103{\cdot}9 \\
\text{Nitric acid, specific gravity, 1·424} \ldots\ldots\ldots\ldots\ldots & = & (HO,\ NO_5 + 2{\cdot}84\ HO) & = & 88{\cdot}5 \\
\hline
 & & HO,\ NO_5 + 2\,(HO,\ SO_3) + 3{\cdot}5\ HO & = & 192{\cdot}4
\end{array}$$

These specific gravities are especially referred to, from their being those of the acids most frequently met with in commerce. Good collodion-wool is also produced by stronger acids, if there be *not less* water than that required by the formula $\left\{\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\} + 3\ HO$, and the temperature is raised to 130°; however, the stronger the acids, the more liable is the collodion-wool to become partially insoluble after drying. If there be less than three additional equivalents of water, the products are equally insoluble whether the acids are employed hot or cold.

Finding that the weighing of the product resulting from the action of warm acids could be of no service in proving the existence of definite compounds, Mr. HARDWICK's suggestion was tried—the effect of reimmersing the cotton in a portion of the same cold acid mixture with which it had been previously treated, noting at the same time whether any second increase of weight was obtained. The results were highly satisfactory. For the preparation of the highest compound, a mixture was made of two volumes of the strongest sulphuric and one volume of colorless nitric acid, specific gravity = 1·521.

27·5 grains of cotton, after some hours' immersion, weighed after washing and drying *in vacuo*, 49·88 grains, corresponding to a gain of 81·34 per cent. In this case, it was hardly expected that a second immersion would cause an increase; by experiment it was found to have sustained a slight loss, as it now weighed 49·62, showing that acids have a slight solvent power, even at ordinary temperatures. This increase of 81·34 per cent. in weight does not correspond with any of the analyses hitherto published, although the greatest care was taken to avoid error, on account of the important aid it would afford in deducing a formula for this and other compounds.

Another mixture agreeing with $\left\{\begin{array}{c} HO, NO_5 \\ 2\,(HO, SO_3) \end{array}\right\} + 4\,HO$, gave at the first immersion an increase of 58·7 per cent.; by a second it was found to have increased to 62·9 per cent., thus fully answering expectations. A third immersion brought it to sixty-four per cent.

On account of the great difference observed between the products of $\left\{\begin{array}{c} HO, NO_5 \\ 2\,HO, SO_3 \end{array}\right\} + 3\,HO$, and the same $+ 4\,HO$, an intermediate mixture was made. The first submersion gave an increase of 67·3 per cent.; a second, 70 per cent.; a third, 71·4 per cent. Hence it was concluded that there were at least three compounds, of which, from one hundred of cotton, there would be obtained quantities approximating to one hundred and sixty-four, one hundred and seventy-two, and one hundred and eighty-two; and it is probable that any acid mixture would produce such a definite compound, were it not diluted at the same time by the water it abstracts, which, when the dilution exceeds a certain point, gives rise to a second compound, the great mass of the liquid probably having but little influence, in consequence of the imperfect diffusion arising from the want of perfect fluidity, and the adhesion to the fibres of the cotton; the washing and *thorough* drying then enable the original acid mixture to raise the second compound to that which would have resulted in the first instance had no dilution occurred. It is evident, also, that the number of immersions required must vary, according as the acid mixture is much within or approaches near to that state of dilution which limits its power of producing a certain compound, a given quantity of water having much more effect in one case than in the other.

In trying the effect of various reagents on gun-cotton, Hadow ascertained that it could be perfectly restored to the original cotton, without loss of form, by means of hydrosulphide of potassium, KS, HS. At Dr. Miller's suggestion, this was made use of, to effect the analysis of the compounds, and to confirm the previous results. An aqueous solution was first tried, but found to occasion loss of weight, on account of the long boiling required; an alcoholic solution was, therefore, prepared, by *thoroughly saturating* a strong alcoholic solution of sulphide of potassium and hydrogen, by transmitting the gas until it would absorb no more, and ceased to give a precipitate in sulphate of magnesia. As, however, the reduction was found to proceed easily at ordinary temperatures, it proved better to effect the change by continuing the immersion for twenty-four hours, and thus to avoid the risk of decomposition and loss which prolonged seething occasioned. That the cotton so obtained was free from nitrogen-compounds was proved by strongly heating it with caustic potassa, and conducting the gases evolved into a solution of litmus very faintly reddened, when the color remained unchanged; by the close correspondence in the quantity obtained from gun-cotton with that originally used, or the restoration back to the original weight; and by its possessing all the physical characters of common cotton, which differs from all products obtained from it by the action of acids in its depolarising action on light, and in its far greater softness and compressibility when wet, and also by the action of $HO, SO_3 + HO$, which dissolves the nitro-compounds, producing a solution which is not blackened below 212°, while common and reduced cotton are completely carbonised below that temperature.

Two combustions of the reduced cotton were made: one, in which the determination of hydrogen failed in consequence of an accident, gave, in one hundred parts, 44·4 of carbon; another, made by Mr. Hardwick, yielded—

	Found.	Calculated.
Carbon,.........	44·86	44·44 = 12 C.
Hydrogen,......	6·64	6·17 = 10 H.
Oxygen,........	48·50	49·39 = 10 O.
	100·00	100·00

The other products of the equivalents of K S, HS are nitrate of potassa—KO, NO_3—and a little ammonia. No trace of nitrate could be discovered in the solution, which was evaporated to dryness with excess of acetic acid, to expel the nitrous acid. An attempt was made to turn the reaction of K S, HS upon gun-cotton to account in effecting the determination of the nitrogen by this means; but the results were unsatisfactory, in consequence of the co-existence of ammonia and nitrous acid in the liquid. The solution could not be heated to expel the former without risk of loss in the weight of the reduced cotton, neither could the ammonia be retained by addition of an acid, without escape of NO_2, from the action of sulphide of hydrogen and nitrous acid on each other.

A mode altogether different was, therefore, adopted, which consisted in making a solution of the compound in pure sulphuric acid, and, after conversion of the oxides of nitrogen into nitric acid, by means of some oxidating agent, estimating its amount by the method of Pelouze, depending on its property of converting proto into sesquichloride of iron, and from the amount of the latter calculating the former. Before performing this, the properties of a solution of gun-cotton in sulphuric acid were examined. A portion immersed in cold concentrated sulphuric acid soon dissolves, without evolution of any gas, producing a clear, colorless liquid; if this be poured at once into five or six times its bulk of water, so that the temperature does not rise before dilution takes place, the clear menstruum obtained gives no evidence whatever of nitric acid, or any oxide of nitrogen, even though raised subsequently to the boiling point; neither does it discolor a solution of permanganate or chromate of potassa. If, however, the original liquid in concentrated acid be diluted with only once, or even twice its bulk of water, a violent effervescence ensues, with abundant evolution of nitrous acid—NO_3—or peroxide of nitrogen—NO_4—together with carbonic acid. If, again, the solution in strong acid be heated before dilution, carbonic acid is evolved, while the oxides of nitrogen are retained, provided that the sulphuric acid is in different excess; if it now be diluted with water, nitric oxide—NO_2—escapes with effervescence. It became necessary, therefore, to effect the complete conversion of the nitrogen oxides into nitric acid. After trial of various oxidising agents, the object was successfully attained by the bichromate of potassa, which immediately peroxidises NO_3 and NO_4, but is without action on NO_2: hence it was necessary to use a solution of gun-cotton in pure sulphuric acid made *in the cold*, which was then added to a strong solution of bichromate contained in a retort; the mixture—which immediately acquired a dark-green tint, from reduction of the chromic acid—was carefully distilled, precaution being taken to insure the entire expulsion of the nitric acid, which was then estimated, as above stated, by PELOUZE'S method.

The quantity of cotton in a given sample of gun-cotton having been determined by reduction by KS, HS, and the nitrogen by the above method, it is easy to see whether the compound contains any equivalents of NO_5, not displacing a like number of equivalents of HO. The following results of analysis leave no doubt that it is purely a substitution-compound :—

Compound A.—Produced by action of the strongest acids, and most probably by *repeated* immersion in any mixture not weaker than $\left.\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 3\,HO$. Quite insoluble in any mixture of ether and alcohol, but soluble in acetic ether. Highly explosive.

I. 27·5 of pure cotton gave, by three hours' immersion in strongest acid, 49·88 first time; 49·6 second time.
II. 6·85 of this gun-cotton gave, by reduction, 3·78 of cotton.
III. 6·37 of gun-cotton, by reduction, gave 3·48 of cotton.
IV 20·50 of gun-cotton gave $NO_5 = 10{\cdot}84$.

	By synthesis. I.	By analysis. II.	III.	By calculation. $C_{36}\,H_{21}\,O_{30}\,9\,NO_4$.
Cotton found,...	55·13	54·6	55·19	54·54
$NO_4 - H$,.....	—	—	44·07	45·46
			99·26	100·00

The composition of cotton being fully determined by the analyses of MITSCHERLICH, PELOUZE, and PAYEN, to be in the proportion of $C_{12}\,H_{10}\,O_{10}$, the preceding analysis would give rise to the formula,

$$\left.\begin{matrix}H_{21}\\C_{36}\,9\,NO_4\end{matrix}\right\}O_{30} = 891.$$

100 of cotton produced 181·34: by calculation, 183·3.

Compound B.—Produced most probably by any acids of composition intermediate between

$$\left.\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 3\tfrac{1}{2}\,HO, \text{ and} \left\{\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 4\,HO.$$

That which was examined was obtained by several immersions in $\left\{\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 3\tfrac{1}{2}\,HO$. It is explosive, yet perfectly soluble in ether $+ \tfrac{1}{8}$ alcohol; quite insoluble in acetic acid.

I. 27·6 grains of cotton gave, by first immersion in the above mixture, 46·2 grains; by the second immersion, 47·1; by the third, 47·31.
II. By reduction, 6·08 grains of the compound gave 3·50 of cotton.

	From synthesis. I.	By analysis. II.	Calculated. $C_{36}\,H_{22}\,O_{30}\,8\,NO_4$
Cotton found,......	58·34	57·56	57·45
$NO_4 - H$,........	—	not determined.	42·55
			100·00

$$\text{Formula would be } \left\{\begin{matrix}H_{22}\\C_{36}\,8\,NO_4\end{matrix}\right\}O_{30} = 846.$$

100 of cotton produced 171·4; by calculation, 174.

Compound C.—Produced by $\left\{\begin{matrix}HO, NO_5\\2(HO, SO_3)\end{matrix}\right\} + 4\,HO$. Like the preceding, this compound is very soluble in ether, but differs from it in being likewise perfectly soluble in *glacial acetic acid.* In this, as in the former compounds, the cotton fibre is quite uninjured. It is highly combustible rather than explosive, and burns with a slow jet of flame when rammed into a tube and ignited.

I. 24·1 grains of cotton weighed, after first immersion, 38·26; after second immersion, 39·26; after third immersion, 39·53.
II. By reduction, 9·94 grains of the compound gave 6·00 of cotton.

	By synthesis. I.	By analysis. II.	By calculation. $C_{36}\,H_{23}\,O_{30}\,7\,NO_4$.
Cotton found,......	60·96	60·36	60·67
$NO_4 - H$,........	—	not determined.	39·33
			100·00

$$\text{Formula, } \left\{\begin{matrix}H_{23}\\C_{36}\,7\,NO_4\end{matrix}\right\}O_3 = 801.$$

100 of cotton produced 164·0: by calculation, 164·8.

Compound D.—The existence, composition, and identity of this compound with xyloidin, are inferred from the following reasons :—

1st. There is a compound lower than C, since $\left.\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 4\,HO$ produces, by one immersion, an increase of only fifty-nine per cent., yet this product is perfectly soluble; if, however, C were the last, all products not attaining sixty-four per cent. in their amount of increase would contain unchanged cotton, and would be only partially soluble.

2nd. The product of the action of $\left\{\begin{matrix}HO, NO_5\\2\,(HO, SO_3)\end{matrix}\right\} + 5\,HO$, in which the texture of the cotton is more or less destroyed, is only partially soluble in ether—cotton, apparently unchanged, remaining behind; it thus appears that the soluble portion is the lowest compound obtainable by the actions of mixed acids on cotton.

3rd. As the next number in the series, its composition would be $C_{30}\left\{\begin{matrix}H_{24}\\ 6\,NO_4\end{matrix}\right\}O_{30}$, which exactly corresponds with that assigned to xyloidin; and one hundred of cotton should yield 155·5. The soluble portion of these products further corresponds with xyloidin in giving an *opaque* film on drying, and in its solubility in glacial acetic acid. Although the xyloidins of woody fibre and starch agree in composition, they may be distinguished by the action of KS, HS, which reduces each to its proximate constituents, when the usual reaction with iodine may be obtained in the one case, but not in the other.

The modifications produced by the action of hot acids have not yet been examined; there is in these cases greater difficulty of avoiding loss in washing, in consequence of their disintegrated state, if immersed sufficiently long to obtain definite compounds. It is evident, however, that there are at least two, produced respectively by $\left\{\begin{matrix}HO,\ NO_5\\ 2\,(HO,\ SO_3)\end{matrix}\right\} + 3\,HO$, and $+ 4\,HO$, since the former becomes insoluble after drying, while the latter remains soluble. All the compounds soluble in ether give transparent films on drying, except D. The presence of this last-named compound is one of the causes of opacity on the drying of some collodions; the other causes are, water in the alcohol or ether, or the presence of acetic ether. All these compounds may be prepared with mixtures containing much larger proportions of sulphuric acid and water; but these have the disadvantage of rapidly dissolving the compounds if used warm.

While endeavoring to ascertain the state in which nitrogen exists in these compounds, HADOW was led to examine the action of caustic potassa on the highest compound, with which, as is well known, it produces a solution capable of reducing salts of silver to a mirror-like surface upon the vessel that contains them. The decomposition of gun-cotton by a solution of potassa takes place slowly at ordinary temperatures, but almost instantly on raising it to 160°. Each portion then immersed causes a considerable extrication of heat, by which the temperature is soon raised to the boiling point, and ammonia is evolved with effervescence. In making the solution for examination, the temperature was kept at 150°, to avoid the formation of secondary products. At this point the gun-cotton quietly disappears without effervescence, producing at last a dark viscid fluid. This was diluted, neutralized with acetic acid, and precipitated by neutral acetate of lead. The filtrate gave a further abundant precipitate with the basic acetate, from which it was at first concluded that there were two distinct acids present; this, however, was afterwards found to arise from the solubility of the plumbous deposit in the acetate of potassa that had been formed, from which solution the basic acetate again throws it down. The liquid filtered from both precipitates contained nitrite and nitrate of potassa. The lead precipitates, after thorough washing on a linen filter, were diffused through water, and decomposed by sulphide of hydrogen, during which process effervescence occurred, with escape of NO_2, showing that, notwithstanding the washings the deposits had undergone, they still retained a portion of nitrate. The brownish solution obtained was again precipitated by acetate of lead, washed, and decomposed as before, when a pale yellow, strongly-acid liquid was obtained, retaining the original reducing power upon the salts of silver unimpaired, and capable of rapidly decomposing carbonates with effervescence. Its power of forming crystalline salts was examined by slowly evaporating a solution of the compound on a slip of glass, and viewing it under a microscope. The ammonia-salt appearing to be the most promising, the liquid was neutralized with ammonia, and allowed to evaporate *in vacuo*. After some time, little tufts of prismatic crystals formed. On examination, however, they were found to be devoid of reducing power, and proved to be oxalate of ammonia. That the oxalic acid had not been formed by the subsequent processes was proved by detecting it in the original solution of gun-cotton in cold aqueous potassa. The liquid, freed from oxalic acid by nitrate of lime, was found to possess many of the characteristics of saccharic acid, such as its property of carrying down nitrites with its lead salts, and its reducing power on salts of silver, which is manifested in both cases on adding to the respective menstrua a portion of a solution of nitrate of silver, ammonia sufficient to cause a clear liquid, and subsequently caustic potassa, without which in either case no mirror-like deposit will take place even on boiling. In certain proportions the color of the reduced silver is identical. Like the neutral saccharates, the neutral salts of this acid, which might be termed pyroxylic acid until its identity with some other is proved, likewise give precipitates with salts of lime, baryta, and cadmium. The principal differences between the two acids are, that no crystalline acid pyroxalate of potassa could be obtained, the solution drying *in vacuo* to a gummy mass, whereas the acid saccharate is very easily crystallised; and that the saccharates of the above-mentioned bases are far more soluble in the heat than in the cold, and are visibly crystalline under the microscope; while the pyroxalates of lime and baryta are but slightly soluble on warming the liquid, and that of cadmium does not redissolve at all on the mere application of heat, though, like the saccharate, it is readily soluble in an excess of the salt of cadmium. The precipitates are likewise all amorphous, with the exception of the lime salt, which has the form of little nodules. HADOW could not further examine the properties of this acid, or obtain a compound with the certainty of its being sufficiently pure for analysis, in consequence of the want of crystalline form and the obstinacy with which a portion of coloring matter is retained.—*Hadow.*

COLLODION.—This substance, which is formed by dissolving gun-cotton in spirit, has of late years been extensively employed in the manner subsequently stated, under the uses of gun-cotton. The following are the best proportions for making it:—

	Parts by weight
Prepared cotton, ...	8
Rectified ether, ...	125
Rectified alcohol, ...	8

Put the cotton with the ether into a well-stopped bottle, and agitate the mixture for some minutes. Then add the alcohol by degrees, and continue to shake until the whole of the liquid acquires a sirupy consistence. It may be then passed through a cloth, the residue strongly pressed, and the liquid kept in a well-secured bottle.

Collodion thus prepared possesses remarkably adhesive properties. A piece of linen or cotton cloth covered with it, and made to adhere by evaporation to the palm of the hand, will support, after a few minutes, without yielding, a weight of from twenty to thirty pounds. Its adhesive power is so great, that the cloth will commonly be torn before it gives way. The collodion cannot be regarded as a perfect solution of the cotton. It contains, suspending and floating in it, a quantity of the vegetal fibre which has escaped the solvent action of the ether. The liquid portion may be separated from these fibres by a filter, but it is doubtful whether this is an advantage. In the evaporation of the liquid, these undissolved fibres, by felting with each other, appear to give a greater degree of tenacity and resistance to the exsiccated mass.

In the preparation of collodion it is indispensable to avoid the presence of *water*, as this renders it less adhesive; hence the ether, as well as the alcohol, should be pure and rectified. The parts to which the collodion is applied should be first thoroughly *dried*, and no water allowed to come in contact with them until all the ether is evaporated.

A method for the preparation of elastic collodion is given by LAURAS. He prefaces it as follows:—

The important improvement to be made in this compound, which hitherto has not been of very frequent application in therapeutics, consists in giving efficacy to it, and in preventing the sufferings produced by its application on any portion of the body, and principally on the articulations, which are much constricted after having been covered with it—an effect due to its want of suppleness and elasticity, and which the skin requires both for stretching and contracting.

By adopting the following formula, every inconvenience is obviated, collodion becomes easy of employment, and enables the patient to move without suffering pain:—

Sulphuric acid, of specific gravity 1·847, three hundred grammes; dry nitrate of potassa, two hundred grammes. These are both mixed together in a stoneware or porcelain pot, and ten grammes of carded cotton added.

Leave in contact for twelve minutes; withdraw the cotton, wash it with cold water to remove the acid which it retains, and after two or three rinsings, immerse it in water containing thirty grammes of carbonate of potassa in solution in one hundred grammes of water; plunge it again into ordinary water, agitate well, and dry at a temperature of 77° to 86°.

The cotton thus prepared takes the name of Xyloidin, and may afterwards be mixed with the ether and the other substances which form it into elastic collodion.

Elastic Collodion.—Xyloidin eight grammes, ordinary ether one hundred and twenty-five grammes. Place in a wide-mouthed flask, and add alcohol of specific gravity ·825 eight grammes. Agitate, and then make a mixture composed of Venice turpentine two grammes; castor oil two grammes; white wax two grammes; ether six grammes. Heat together the first three substances, add the ether, and combine the two mixtures.

ADULTERATION.—Should it be desired to ascertain whether ordinary carded cotton has not been added to sophisticate the gun-cotton, it may be arrived at by the following micro-chemical process. A small portion of the cotton is impregnated with a solution of iodine, and a drop of sulphuric acid added, and then submitted to the lens; the gun-cotton is very feebly affected by this treatment, and retains the yellow coloration communicated by the iodine only slightly intensified after some time, whilst under the same treatment the fibres of ordinary cotton would quickly disintegrate, and partake of a lively violet hue. The intensity of the latter will be a comparative indication of the probable amount of the adulterants.

USES.—Many attempts have been made to apply gun-cotton to mining purposes on account of its enormous explosive force, and the small quantity of smoke which it produces; but the objections to its use are numerous, the most fatal one being its liability to spontaneous ignition.

Gun-cotton continues to be an object of great interest on account of its application to the beautiful art of photography. When the cotton is prepared in such a way as to burn slowly, it is not liable to spontaneous ignition, and it is in this state perfectly soluble in ether, which the more explosive cotton is not. If the ethereal solution be poured on the surface of cold water, a paper is produced, which is prepared for the use of the photographer. This paper is a very active electric, and is perfectly soluble in ether. Collodion has also been made use of in surgery, by applying the ethereal solution to a wound, when a thin delicate artificial skin is formed by it, which perfectly excludes the air.—*Encyclopedia Britannica.*

GUNPOWDER.—*Poudre à canon*, French; *Schiesspulver*, German.—The article which bears this title is a singular mixture of nitrate of potassa—saltpetre—sulphur, and charcoal, and is so well known for its remarkable properties by every one, that it is unnecessary to enter into a detailed exposition of it. Regarding its manufacture and the uses to which it is devoted, however, in a true light, its importance as an agent of power, which places it side by side with steam at the present day, cannot fail to render it an object of deep research and inquiry.

It might well be said that no other branch of industry has, during many years, decided the destinies of people so much as gunpowder. Sometimes favorable to the progress of civilization, powder offers to the miner and engineer a ready and sure means of breaking all obstacles which intercept their progress in their labors; sometimes, on occasions of festivity, it becomes in the hands of the artificer a symbol of joyful public rejoicings; and, finally, on occasions of civil strife and warfare, it turns out to be a sure instrument of death and massacre—spreading the devastating bullet or shell with an effect which lays nations of greatness and pomp level with the dust, and raises others to the dignity of empires.

The invention of gunpowder formed a grand epoch in the world's history. Tomlinson ascribes it to Barthold Schwartz, a German monk and alchemist, and the date of the discovery is supposed to be about the year 1320. The prior claims of Roger Bacon, whatever they be, are, however, unquestionable, as this substance is described in his writings about the year 1270, or half a century before the supposed discovery by Schwartz. But even Bacon himself has as little title to the invention as his imagined rival; nor, indeed, when his own description of this then wonderful compound is examined, can it be perceived that he makes any claim to be the discoverer. On the contrary, he quotes it as a well-known substance in common use all over the world, for making squibs for the amusement of children—so pertinacious are vulgar errors. Dutens attempts to show that the claim, which certainly does not belong to Bacon, is removed to Magnus Græcus, whose manuscript he quotes, and from which he presumes Bacon derives his knowledge of the invention; although, by his own showing, Bacon need not have consulted an obscure writing for an invention of general notoriety. In the same manuscript are contained directions for making a rocket, which are such as to prove that the nature of this firework was thoroughly understood. It is even remarkable that he recommends the charcoal of willow wood, which the moderns have found by experience to be amongst the best for such purposes.

Thus far the date of the origin of gunpowder has been traced, not only beyond Bacon, but beyond this supposed predecessor, as he himself professes to be a *compiler*, not an author of the *Liber Ignium*, as he denominates his treatise. If, in attempting to ascend still higher, the evidence becomes more rare and illegible, there are still insuperable facts to prove that its antiquity is far greater, however impossible it may be to approximate to the date of the invention, much less to assign that which appears to be buried amongst the obscurities of oriental learning. The question of gunpowder as applied to artillery is a separate one; but there is abundant reason to believe that this compound was not only used in some form or other as an explosive and combustible substance, but that it was applied even to military purposes—it may be, in the shape of rockets or other fireworks, which, for objects of amusement at least, have been familiar to the Chinese beyond all record.

The earliest date to which the knowledge of gunpowder can be referred, in defect of a sufficiently remote acquaintance with oriental history, is 355 before Christ, although, from the very nature of this attestation, it follows that it was then not only known to the Eastern nations, but that it must have long been so, since, even at that early period, it was applied to warlike purposes. In the code of Hindoo laws, indeed, where it is mentioned, it is referred to an era which oriental antiquaries have considered as coincident with the time of Moses. But the evidence to which more particular allusion is made, is found in a passage of the *Life of Apollonius Tyanæus* by Philostratus, the purport of which is that Alexander was unwilling to attack the Oxydracæ, who lived between the Hyphasis and the Ganges, because they were under the care of the gods, and overthrew their enemies with thunder and lightning which they shot from their walls. The same account is given of the repulses experienced in this country by Hercules and Bacchus.

The next of these early dates, in which also the evidence is imperfect, is 212 before Christ; but the establishment of the proof of the last would render this one more credible. In the defence of Syracuse by Archimedes, Vitruvius relates that one of his engines threw stones with a great noise—a description which does not apply to any of the mechanical artillery of the ancients. On a notice so superficial, however, much stress must not be laid, and here ends all the information respecting the earliest knowledge of gunpowder. It seems, however, so decidedly capable of being traced from the East, through the intervention of the Arabs, that there can be little doubt of its oriental origin, and of its being thence imported into Europe. Indeed, the military use of rockets in the armies of India ascends to a very remote period.

Of the earliest date at which it was known in China, their own evidence is defective; but Uffano, an Italian author, affirms that not only gunpowder, but ordnance, was in use in that nation in the year 85, and that in his day cannon were remaining from the most ancient times in some of the maritime provinces, made both of iron and of brass. Hence some writers presume that the Chinese communicated the invention to the Indians; whilst it has also been said, but on no sufficient authority, that they themselves received it from Tartary—a nation respecting which little or nothing is known and in which one would not be inclined to look for an early acquaintance with the arts. This, however, refers to a date so late as 917; so that, if there is any dependence to be placed on the Indian and Chinese hypothesis, the Tartars must themselves have borrowed the invention from those to whom they are said to have lent it.

There is after this a long blank; and the first author on the subject is an Arabic writer, in the Escurial collection, whose work, bearing date 1249—about twenty years before the date of Bacon's narrative—is translated by Casiri. His description is such that it may apply both to rockets and to shells. In the former case, it only involves the knowledge of the detonating compound; the latter, were it proved, would show that they were also acquainted with the use of ordnance, although it is not impossible but that such projectiles might have been thrown by mechanical artillery.

As the invention of gunpowder has been popularly ascribed to Bacon and to Schwartz, so the use of ordnance has been referred to the time of the battle of Cressy—1346. To pass over the Chinese hypothesis on this part of the subject, it will be found that cannon were known at least as early as the year 1312. This is derived from the source quoted by Casiri: from Arabian writers who in 1312 and 1323 describe the use of ordnance; whilst, if Barbour is to be trusted, Edward III. was also provided with some pieces of artillery in 1327, and Père Daniel asserts that cannon were known to the French in 1338. This discussion need not be carried lower; though, in favor of the oriental origin of the invention, it may be remarked, that artillery was much in use in the Mediterranean when it was still but little used elsewhere; as by the Venetians in 1380 against Genoa, and by ALPHONSO XI. in his wars with the Moors.—*Encyclopedia Britannica.*

In the prolegomena it was stated that gunpowder is a composition of definite quantities of sulphur, saltpetre, and charcoal. From time to time various experiments have been conducted with considerable care for the sake of determining the most convenient proportions of the foregoing substances; and, singularly enough, people have, in almost every instance, fallen back upon the recipes given by the most ancient writers upon the production of this article. The knowledge that powder owes its extraordinary effects to the sudden transformation of its solid constituents into permanent gases, the volume of which is enlarged by the temperature resulting from the chemical action producing this change, will at once lead to the conclusion, that all matters incapable of undergoing such a modification injure or depreciate, in proportion to their quantity, the quality and efficacy of the product. Hence it should always be the desire of the manufacturer to use the purest materials; and, to assist him in his business, they will be considered here.

MATERIALS.—The greatest care is requisite in the preparation of pure ingredients for the manufacture of gunpowder.

The principal saline impurity in saltpetre is chloride of sodium—common salt—which has a very injurious action upon gunpowder, causing it to absorb moisture, whereby its power is soon considerably weakened. Saltpetre containing more than a three-thousandth part of chlorides, is rejected as unfit for use.

The solubility of saltpetre at 212° is about fourteen times greater than it is at ordinary temperatures, while that of chloride of potassium is only about twice as great, and that of chloride of sodium is but slightly increased. If, therefore, a solution containing these three salts be concentrated, the greater quantities of the chlorides will be deposited as the water decreases, even before the nitrate of potassa exhibits any symptom of crystallizing out. This separation is effected in practice, by placing a perforated iron ladle or dish on the bottom of the boiler in which the solution is being concentrated. The chlorides, as they separate by the evaporation of the water, deposit upon the dish, and may from time to time be removed. When small needles of nitrate of potassa begin to appear, the menstruum is run off into the crystallizing cooler, from which tolerably pure saltpetre will be obtained, to be refined by a similar operation.

At Waltham Abbey the refining of saltpetre is effected by first decolorizing its solution by ebullition with newly-burnt charcoal, and then by repeated crystallization. Great care must be exercised in this process, which will be fully dwelt upon under POTASSA.

Sulphur, as employed for the manufacture of gunpowder, is generally in the sublimed state, or that known in common parlance as *flowers of sulphur.* These are obtained by conducting the vapor of sulphur into large chambers, the sides of which must be kept cool. The sulphur condenses in the form of a fine crystalline lemon-yellow powder. When the sides of the chamber become heated, the sulphur fuses, becomes limpid, and trickles down to the base of the chamber. To prevent this, which, of course, would spoil the whole deposit of flowers, as soon as the walls of the chamber get too warm, the communication between the latter and the retort is closed, and another one opened, leading into a metal receiver; the sulphur is allowed to distil over into this until the first chamber has become sufficiently cool, and the flowers have been collected from its sides, when the vapors are again passed into it.

The sublimed sulphur sometimes requires washing, in order to free it from the sulphuric acid which is generally formed with it, and which is caused by the oxidation of the sulphurous vapors by means of the common air which pervades the condensing chamber previous to the commencement of the distillation of each charge.

It has been suggested that the sulphuric acid should be removed by allowing the sulphur to remain between damp cloths for some time previous to use.

Charcoal.—The third principal constituent of gunpowder is charcoal reduced to an impalpable state. This constituent demands no less attention in the selection than the other components; for much of the efficiency of the powder depends upon its possessing such qualities as experience has shown to be required. Even in the time of MAGNUS GRÆCUS, as already mentioned in the preceding historical notice, the charcoal of willow-wood was preferred, and experience has fully proved that the charcoal of the soft woods always produces the best results. Some time since, dogwood was adopted, as giving the most friable charcoal; but it has since been shown that the woods of the willow, poplar, black alder, and chestnut trees afford equally suitable products. The hard woods are invariably rejected, and with justice; though the presence in them of deleterious salts is not the only objection to their use.

Two considerations must not be overlooked in choosing a proper charcoal—namely, the nature of the wood, and the manner in which the carbonization of the same is conducted; and each demands the utmost circumspection in the manufacturer who is desirous of producing an article which will yield the greatest possible amount of force, and combine at the same time the quality of inflaming readily, as well as that of leaving the least quantity of residuary matter after its ignition.

There is no doubt, says the writer of the article GUNPOWDER in the *Encyclopedia Britannica*, that wood which contains carbonate of potassa or other deliquescent salts, is unfit for the purpose, and for obvious causes. This is the case in the oak, elm, fir, and other trees. But there is another reason for the badness of these kinds of charcoal, which is not so obvious, although it is evidently connected with their hardness. It appears to depend on the small proportion of hydrogen combined with the carbon in these charcoals, compared to that which exists in the produce of the softer woods. Even these can be reduced to the same state by subjecting them to higher temperatures. Thus the hydrogen is dissipated, the charcoal becoming so hard as to scratch steel; in which case, however obtained, it is unfit for gunpowder.

Thus experience has found, from time to time, how ill-adapted for this manufacture are many of the charcoals usually prepared; but such acquisitions were frequently gained at the expense of a loss sustained by the failure of some experiment. In later times, however, scientific research clears the path for the manufacturer to some extent, so that he who desires to progress has not to confide in the results of haphazard experiments, the principles of which may be but ill understood, but rather decide according to the conclusions drawn from the well-contrived investigation on the subject. **Proust** is one of those who has made the materials and preparation of gunpowder his study, and from them considerable information may be gained. With the view of finding the best quality of charcoal, he practised the following ready and simple means. He makes a mixture of twelve grains of the charcoal and sixty-two of nitrate of potassa by careful grinding in a mortar, and then introduces it on a small tray into a copper tube two and a half inches in length by three lines in diameter; he primes on the top of this with a little fowling powder, and when this is done, the lower part of the tube is fitted in a dish of cork, or other light material, which is floated on the surface of water. It is evident from these arrangements, analogous as they are to those under which the powder is inflamed, that the mixture which burns the more readily is that which is most suited to the manufacture. By experiments conducted in this way, and with all the precautions available under the circumstances, **Proust** obtained the following results:—

Mixture of sixty-two grains of saltpetre and twelve of charcoal.	Time of the combustion in seconds.	Weight of residue in grains.
From hemp or hemp husk,	10	12
" stalks of asphodel,	10	12
" vine branches,	12	20
" pea stalks,	13	21
" pine,	17	30
" bourdaine,	20	24
" spindle-tree,	21	27
" hazle,	23	30
" maize canes,	25	38
" chestnut-tree,	26	36
" walnut-tree,	29	33
" maize,	55	43
" coal-coke,	50	45
" sugar,	70	48

When submitted to the same operation, he found that the charcoal produced from starch, wheat, rice, gall-nuts, indigo, gluten, gelatin, albumen, blood, and skin, and, in fact, those derived from all animal matters, would not undergo combustion.

From the foregoing table it is evident that those which precede the charcoal from hazlewood rise in the scale of superior fitness, whilst those beneath the latter evidently descend, and are not well adapted for the manufacture.

Other experiments upon the same subject, founding the comparison of the different charcoals upon the volume of gas which they yielded when ignited with saltpetre, have been conducted by French and British chemists, and the results are tabulated below. In each case the proportions used by the former were sixty grains of nitrate of potassa to twelve of charcoal; but in the latter the calculations are made to correspond with the same standard:—

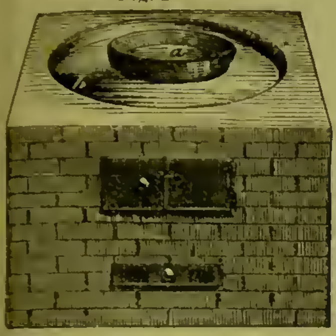
Charcoal.	Proportion of gas in cubic inches.	Residue in grains
From French hemp stalks,	62	12
" asphodel,	62	29
" vine,	64	20
" pea stalks,	62	21
" spindle-tree,	66	25
" fir,	66	39
" chestnut,	66	36
" hazle,	66	33
" lamp-black,	54	44
" coke,	54	45
" filbert,	72	39

Much of the interest which might otherwise be taken in the foregoing results of the French chemists is lost, on account of the subjects being not likely ever to enter practically, at least to any extent, into the manufacture under consideration. Below are given results arrived at in England, by operating upon the more frequently-occurring woods:—

	Proportion of gas
Filbert,	72
Oak,	61–63
Mahogany,	58
Elm,	62
Willow—*Salix Alba*,	76–78
Alder,	74–73
Dogwood—*Rhamnus frangula*,	80–82–84
Oak bark,	58
Animal charcoal,	50-46–42–40
Coke,	52–48
Lamp-black,	54–52
Oak charcoal overheated,	54–56
Willow " "	59 64–66

Tomlinson attributes much of the difference in the latter table to the method in which the charcoal is prepared, rather than to the substance itself, since he considers that to overheat the matter in its carbonization is injurious to its power of combustion. This is evidenced by the results which the modified charcoal from oak and willow afforded; and, in fact, several researches have led to the acknowledgment of the same fact. **Violette** has shown that the most combustible charcoal loses this quality in proportion as the heat applied in the carbonization is raised, till ultimately, when the charring is made at the fusing point of platinum, the product obtained is so incombustible as to be ignited with difficulty even when the heat is 2282°. During his researches upon the carbonization of wood and the application of charcoal, he examined with considerable skill and acuteness the various products which most of the ordinary woods afford by charring, in reference to their combustibility in air, and the temperature of their ignition according to the caloric applied in their manufacture, and also with regard to the same kind of charcoal when subjected to an increasing heat in close vessels; the temperature at which charcoals decompose nitrate of potassa, as well when they are the result of a standard degree of heat, as when this degree has been varied in their manufacture. To these researches he has coupled the estimation of the necessary caloric required for sulphur to decompose the saltpetre, and that at which it burns in air, and many others; such as the thermometric degree at which powder is ignited, the several mixtures used for the manufacture of powder with regard to the amount of their constituents, *et* *cetera*, to which reference will be made in their respective places. As the susceptibility of charcoal taking fire is a subject which, to those who are under the necessity of storing it for some time in magazines, is highly interesting, it may be well to lay before the reader the procedure of VIOLETTE, for the estimation of the degree of heat at which charcoals enter spontaneously into combustion.

Fig. 246.



He adopted an apparatus similar to Fig. 246, in which A is a small flat plate-iron basin, floating upon a bath of tin or pewter, B, which is heated by a fire at C. The pieces of charcoal, prepared in pellets 0·01 inches in length and 0·001 in thickness, were placed symmetrically in the basin, A, and the fire urged, thus increasing the heat of the tin bath, and, consequently, that of the small iron basin containing the cylinders of charcoal. The order of their inflammability was noted as each, in succession, gave indications of combustion by a luminous point appearing upon the circumference of the superior section, and which quickly enveloped the whole surface, and resulted in leaving only the ash. In the following table, the series in the column A show the order of the spontaneous ignition of the materials which had been thoroughly charred, whilst those in B represent the order with reference to brown charcoals, or such as retained a portion of their constituents, and, therefore, had only been but imperfectly made :—

SERIES A.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
1		500°
2	270°	518
3	280	536
4	290	554
7	300	572
9	310	590
10	320	608
11	330	626
12	340	644
13	350	662
21	432	819
22	1023	1873·6
23	1300	2372
24	1500	2732

SERIES B.

The order of the ignition of charcoal.	Temperature of the carbonization of charcoal.	
"	"	"
"	"	"
5	250°	482°
6	230	446
8	240	464
14	220	428
15	210	410
16	190	374
17	170	338
18	200	392
19	180	356
20	160	320

From the above, it may be inferred that charcoal, prepared at 500°, is the most liable to undergo spontaneous combustion. It is remarkable that the phenomena observed with regard to the brown or torrefied woods in the second column, before their entering into ignition of complete carbonization, was effected first, as indicated by the quantities of fumes which were disengaged from them ; *id est*, they were converted into a charcoal such as that prepared at 500°. As soon as this condition was attained, they underwent spontaneous ignition. In the second place, it is easy to see that the inflammability of the charcoals decreases in proportion as the temperature of their preparation is more elevated. To make the examination more definite than the comparative but necessarily indeterminate one above mentioned, the following process was followed :—A porcelain crucible was selected, and about sixty grammes of saltpetre fused in it. The bulb of a mercurial thermometer immersed in it, showed that the melting occurred at 644°. Gradually pieces of the most inflammable charcoal, such as those prepared at 500°, were projected into the molten mass, and the crucible quickly inclosed to prevent cooling by radiation ; on taking the cover off, the particles of charcoal were observed to be undergoing several commotions, but without taking fire, notwithstanding that, by increasing the heat only 1·8°, the matter burned. Hence it may be stated, that charcoal obtained at 500° ignites spontaneously at 645·8° or 646°. On increasing the temperature of the crucible and nitrate of potassa by regular increments of heat, it was found that charcoals prepared at temperatures from—

500° to 536°	ignited at	680°
536 to 662	"	698

On raising the heat a little above 698°, the charcoal resulting at 819° ignited, but the other kinds, produced at a higher heat, refused to burn. As the thermometer ceased to indicate truly any higher heat, the bath had to be changed for one of pewter or tin. Having introduced the more incombustible charcoals, then gently raised the temperature with a charcoal fire till near the point of redness, they began to show the first signs of combustion.

In the annexed table the results are tabulated :—

The temperature at which charcoal has been carbonized.		The temperature at which the charcoals have taken fire.
260°	= 500°	340° — 680°
270	= 518	340 to 360 — 680 to 698
280	= 536	
290	= 554	360 to 370 — 698 to 716
300	— 572	
310	— 590	
320	— 608	
330	— 626	
340	— 644	
350	— 662	
432	— 819	
1023	— 1873·6	600 to 800 — 112 to 1472
1250	— 2282	
1300	— 2372	
1500	— 2732	
Charcoals made at temperatures which fuse platinum,........		1250 — 2280

The foregoing determinations possess a peculiar interest for the powder manufacturer, especially when it is understood that frequently charcoal, produced at temperatures between 500° and 662°, are employed for the purposes of sporting powder; the black kinds obtained at a higher heat, such as 819° or so, being reserved for the article in demand for the military and mining requirements. Now, since the first kind ignites spontaneously at 680°, the origin of the various explosions happening in powder mills may be easily traced. The increase of temperature by friction during the grinding, more especially when this is done by metallic bodies, often reaches the preceding degree, and, consequently, supplies the necessary conditions for inducing combustion in the mass; again, when placed in the state of fine powder in the recipients, it condenses so much air in its pores that the heat, which is a well-known result of such a condensation, is sometimes elevated to the above standard. Probably the compression referred to is not made without a chemical combination of a part of the oxygen with the hydrocarbon in the charcoal, and such slow combustion, gathering greater force as it progresses, may be in the end sufficiently active to ignite the whole mass.

VIOLETTE further examined several varieties of charcoal, all of which were prepared at 572° by both the foregoing methods; they inflamed between 680° and 716°, but in no case did they take fire at a lower heat than 680°. He observed that the charcoals from light woods generally ignited a little before the product from the harder kinds, with the exception of one, which is remarkable, namely, the charred product of the fungoid excrescence of the willow tree (*agaric de saule*). The latter was observed to take fire in one instance at a temperature so low as 572°, and in every experiment at 608°. Hence it is the most inflammable of all species of charcoal; and, as the above-named investigator remarks, had it been prepared at 500° instead of at 572°, doubtless its spontaneous combustion would take place at a lower temperature than even that given. It may well be inquired to what may this peculiarity be attributed? and, doubtless, as VIOLETTE suggests, the organic molecular state of the substance might exercise some influence whereby its rapid ignition is induced.

To sum up these results, it will be seen—

1. That the most inflammable of all wood charcoals (*agaric de saule*) takes place at 572°.

2. That the charcoals from different kinds of wood, when prepared at a constant heat of 572°, spontaneously ignite between 698° and 734°, according to the nature of the wood producing them; but that the product from the lighter burns quicker than that of the denser woods.

3. That charcoals from the same wood, only prepared at increasing temperatures, spontaneously undergo combustion at very unequal degrees of heat, as shown in the table, page 50, *ante*.

After attentively considering these results, very little doubt will remain as to the best means of carbonizing the wood. To a certainty the temperature of the charcoal, as prepared by most of the methods indicated under the charring of wood, vol. ii., *et seq.*, and also under ACETIC ACID, exceeds the limits laid down by VIOLETTE; and, therefore, it follows that the combustion of a powder made by such materials will require a greater amount of caloric to induce its decomposition than if the charring heat was less. Where the process by superheated steam or gases is not adopted, evidently the choice should be decided in favor of that method which furnishes the charcoal at the lowest degree of heat. There are three methods in ordinary use by which the charcoal for the powder manufacturer is prepared, namely, the pit, the furnace, and the close retort. When pits are selected, they are made smaller than those described in the foregoing articles, and the walls and sides, together with the apertures for the introduction of air, are constructed with more care; the wood is also arranged in them with greater caution, and the combustion watched so that, during the operation, the whole may be completely acted upon, and no half-burned material left. In the general particulars, however, no difference exists between the methods already alluded to and this, so that it will be needless to repeat the description. The product amounts to sixteen or seventeen per cent. of the wood. If the carbonization is effected in furnaces, the quantity of the product will not be so large; besides the consumption of fuel will be greater than in the preceding case. In England, however, the charcoal obtained by the distillatory process in closed retorts is always preferred, although a considerable expenditure of fuel is occasioned in heating the vessels. The apparatus described at vol. i., page 17, is the same as used in this operation. When the process of carbonization is coming to a close, the pipe connecting the cylinder with the pyroligneous-acid receiver must be closed, and very free egress must be allowed for the volatile matter; otherwise the charcoal is liable to injury by the deposition of a fuliginous varnish, and even by its reception of, and saturation with, condensable matter.

TOMLINSON, who writes the excellent article GUNPOWDER in the *Encyclopedia Britannica*, is inclined to consider this preference for distilled charcoal a mistake of the *causa pro non causa*. Pit charcoal, being made in coppice woods, is always the produce of oak; and it is probable that this wood, if charred in close vessels, would be even worse than it is now. There is more danger of overheating in the retort than in the pit, while the wood is not better burned; and hence, by a careless management of the process, even the charcoal of willow and alder may be rendered as bad as that of oak. Considering these various circumstances, charcoal requires to be submitted to three tests. It ought to act as little as possible mechanically, even on copper; no salts should be extracted from it by treating it with boiling distilled water; and it ought to give out no smoke when heated. The latter test is indicative of its being thoroughly burned.

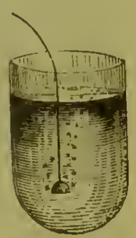
The selected wood, whatever its variety, should always be cut when in sap, and never when dead. Wood of five or six years' growth is better suited for the manufacture of the charcoal than older kinds; for, generally, the latter contains more mineral matters, and, consequently, less carbon than the former; and the most convenient size is branches from three-quarters to an inch in diameter.

The charcoal, says Dr. URE, is considered by the scientific manufacturers to be the ingredient most influential, by its fluctuating qualities, upon the composition of gunpowder; and, therefore, it ought always to be prepared under vigilant and skilful superintendence. If it has been kept for some time, or quenched at first with water, it is unsuitable for the purpose. Charcoal extinguished in a close vessel by exclusion of air, and afterwards by exposure to the atmosphere, absorbs only from three to four per cent. of moisture, while red-hot charcoal quenched with water may lose, by drying, twenty-nine per cent. When the latter sort is used for gunpowder, a deduction of weight must be made for the water present. Charcoal, however, which has remained long impregnated with moisture, constitutes a most detrimental ingredient of gunpowder.

Before entering upon the description of the process for compounding the substances which constitute gunpowder, it may be well to give a few additional facts relative to the circumstances which affect the mutual decomposition of those bodies as they exist in this article, and render the phenomena of its explosion more easy of comprehension. Already some experiments of PROUST have been adduced, which elicit comparative data of the explosiveness of certain varieties of charcoal when mixed intimately with saltpetre; but they do not afford any real knowledge as to the degree of heat required to bring about such a metamorphosis, although they indicate that some kinds of charcoal form more inflammable mixtures with nitrate of potassa than others. The investigation of VIOLETTE upon the temperature at which charcoal decomposes this agent, is much more definite, and consequently interesting. He found that the degree of caloric which occasions the combustion of charcoal in the air, is much lower than what is necessary to cause the carbonaceous matter to decompose the oxidising agent which is incorporated with it in the powder. To determine this, he proceeded thus:—In a small porcelain crucible, heated by a carcel-lamp, which allowed the temperature to be easily regulated, nitrate of potassa was melted and maintained at 680°, being the degree at which the charcoals burned in the air. Into this bath a small cylinder of charcoal appended to a platinum wire, or glass rod, is plunged, so that it is all submerged; although numerous bubbles of gas were disengaged, yet the carbonaceous mass did not take fire at this temperature. By raising the heat gradually to 716°, and, trying the experiment at this stage, the effect was still negative, but ultimately it deflagrated after the bath had been raised to a higher degree of heat. The fusion of lead and zinc showed the thermometric effect to be above 680°; but it being incapable of melting antimony, it was evident that the heat had not reached 819°, the fusing point of the latter metal. It may be concluded, therefore, that all charcoals prepared between 500° and under to 819° decompose nitrate of potassa at 752°, but that such as are obtained between 1832° and 2732° are not affected at the preceding, nor at much higher heat, since they do not even burn upon the surface of the bath.

The same chemist determined the degree of heat at which sulphur decomposes nitrate of potassa in an equally ingenious way. He found that when sulphur was thrown upon the surface of the bath of fused salt, raised to the temperature of 680°, it floated about, melted, and inflamed; the combination, however, was with the oxygen of the air, and none of the saltpetre had been acted upon. A similar result was arrived at when the bath was at 752°, or even a few degrees higher; but when it had attained 819°, the fusing point of antimony, deflagration occurred by the decomposition of the potassa salt, and the evolution of a brilliant white light and a considerable quantity of gases. In the latter experiments it was necessary that the sulphur, like the charcoal in the last-mentioned examination, should be immersed in the fluid bath. To do this, VIOLETTE had a platinum crucible about the size of a pea constructed, and to this he appended a platinum wire, which might serve as a holder to it when immersed, mouth-under, in the bath. When 0·1 grain of sulphur was melted in this tiny vessel, and plunged into the bath in the manner shown in the annexed diagram, the effect was observed with considerable accuracy. Until the heat had reached the decomposing degree, the sulphur was observed to ascend in bubbles of colorless vapor through the transparent bath, and burst into a beautiful blue flame. As soon as the inflammation of the sulphur commenced within the fused saltpetre, the white light traversed the whole mass with the effect already detailed.

Fig. 247.



An observation of VIOLETTE's is worthy of notice here. During his examinations of the combustion of sulphur in nitrate of potassa, he tried at what temperature this element burns in the air, but found that the limits which are stated with reference to it in chemical treatises differed, both from one another as well as from his results. DUMAS gives the combustion of sulphur in air as taking place at 302°; DALTON states that the heat is 500°, and THOMSON, 561°; but VIOLETTE affirms the melting point to be exactly 480°. His experiments were performed on the surface of a bath of tin; contact of the sulphur and metal being avoided by placing it upon a thin pellicle of glass, and floating the latter upon the hot metal.

It was also observed that by sprinkling a little sulphur upon charcoal thrown upon the surface of the heated bath, ignition took place under the degree at which the most combustible charcoal kindles, *per se*. This occurs on account of the heat developed by the combustion of the sulphur at 480°, and which brings the charcoal to the state of redness, and consequently at which, when air is supplied, it rapidly inflames.

PROPORTIONS OF THE INGREDIENTS.—The progress of improvement in determining the proportions of the constituents of gunpowder, has been very gradual. In this country, a long period elapsed before the present state of perfection was attained; but this cannot well be wondered at, when one takes into consideration the ignorance which existed even up to the commencement of the present century, not only with regard to the theoretical laws of science, but also in respect of the properties of bodies purely chemical.

Such compounds as saltpetre, sulphur, and charcoal in equal proportions were scarcely fit for squibs, much less for the purpose of projecting shot. Again, one finds such mixtures as saltpetre twelve parts, with three each of charcoal and sulphur; twenty-seven of nitrate of potassa to three of each of the other ingredients; saltpetre forty-eight, sulphur seven, and charcoal three parts; with many others which now-a-days appear equally ridiculous. At no very distant period, the French compositions were, saltpetre fifty, sulphur sixteen, charcoal thirty-four parts; saltpetre sixty-seven, sulphur thirteen, charcoal twenty; and again, saltpetre eighty-four, sulphur eight, and charcoal eight parts.

BAPTISTA PORTA was one of the first who endeavored to ascertain the best relative quantities of the constituents, and his proportions, obtained in the year 1515, approached very nearly those now employed in France. The deductions of GUYTON MORVEAU, BEAUMÉ, CHAPTAL, PROUST, and RIFFAULT, are represented below:—

DUMAS gives the proportions, saltpetre 75, sulphur 12·5, and charcoal 12·5, as the most ancient known, and states, that however these proportions have been deviated from, either from pressing circumstances of time or place, the powder manufacturer had in the end to fall back upon the above mixture as offering the best composition. This seems to be the case, since the researches of the several original chemists who have taken up the question give mixtures closely approximating to those numbers, as may be seen from the annexed table of the mixtures recommended by them.

	Saltpetre.	Sulphur.	Charcoal.
Guyton Morveau, ...	76	 9	 15
“ “	77	 7	 17
“ “	80	 5	 15
Beaumé, ...	80	 5	 15
Chaptal, ...	77	 9	 14
Proust, ...	78	 9	 13

To these may be added the following:—

	Saltpetre.	Sulphur.	Charcoal.
Powder of Bâle, ...	75·0	 10	 14
“ Grenelle,............	76·0	 12	 12
“ Riffault,...............	77·5	.... 7·5	 15
“ Bouchet,.............	77·0	.... 9·5	.... 13·5

Of the latter class, that of Bâle is accounted the best for military and general warlike purposes; but, notwithstanding the superiority it possesses when recently prepared, if the compound has to be retained for a long time in magazines or to endure long transport, it does not answer so well as the old proportions above referred to. Theoretically considered, this is, granting that all the materials possessed absolute purity, the best composition; for if the nature of decomposition of powder be attended to, and the products of the combustion examined, it will appear that only carbonic acid, nitrogen, and an alkaline sulphide are produced. Hence it may be reasonably inferred that the chemical symbol corresponding with this decomposition, admitting of no loss, would be,—

$$\underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} + \underbrace{3\,C}_{\text{Carbon.}} + \underbrace{S}_{\text{Sulphur.}} = \underbrace{K\,S}_{\text{Sulphide of potassium.}} + \underbrace{3\,CO_2}_{\text{Carbonic acid.}} + \underbrace{N}_{\text{Nitrogen.}}$$

—that is, one equivalent of saltpetre, three of charcoal, and one of sulphur, by being made into a powder, affords one equivalent of sulphide of potassium, three of carbonic acid, and one of nitrogen. Calculating from these data the percentage quantity of each to be taken, the annexed results are obtained:—

		Theoretically	Practically
1 Eq. of nitrate of potassa, ...	101	.... 74·81 =	75·0
1 Eq. of sulphur,..............	16	.... 11·85 =	12·5
3 Eqs. of carbon,..............	18	.... 13·34 =	12·5
	135	100·00	100·00

The difference between these numbers is so minute as to be worth noticing, even were nothing else to be taken into account; but as shown by the analysis of several charcoals, as given under FUEL, there is always more or less hydrogen present, which concurs to make the combination more complete, and in accordance with theoretical results. Another instance of the accuracy of the quantities taken for the preparation of another quality of powder, is the variety generally used for mining and blasting purposes. The proportions taken for this are:—

Saltpetre, 65; sulphur, 20; charcoal, 15;

Numbers which closely correspond with the formula.—

$$\underbrace{KO\ NO_5}_{\text{Nitrate of potassa.}} + \underbrace{S_2}_{\text{Sulphur.}} + \underbrace{4\,C}_{\text{Charcoal.}} = \underbrace{KS_2}_{\text{Bisulphide of potassium.}} + \underbrace{2\,CO}_{\text{Carbonic acid.}} + \underbrace{2\,CO_2}_{\text{Carbonic acid.}} + N$$

		Centesimally.
1 Eq. of nitrate of potassa,..........	101 =	64·33
2 Eqs. of sulphur, ...	32 =	20·44
4 Eqs. of charcoal, ...	24 =	15·23
	157	100·00

Sporting powder is another of these compositions which may be reduced to the simplicity and certainty of a chemical formula. The usual quantities of the materials taken in this case are:—

Saltpetre, 78; sulphur, 10; charcoal, 12;

Numbers which may be expressed by equation, although this is not so simple as the preceding, owing to there being a slight excess of oxygen over and above what the charcoal combines with, and the amount of sulphur used being incapable of retaining all the potassium in the state of sulphide. This will be seen from the formula,—

$$8\,(KO, NO_5) + 6\,S + 23\,C = 5\,KS + 2\,(KO, CO_2) + 21\,CO_2 + N_8$$

That is, eight equivalents of saltpetre, six of sulphur, and twenty-three of carbon, afford five equivalents of sulphide of potassium, two of carbonate of potassa, and twenty-one of carbonic acid and eight of nitrogen. The truth of the formula is proved in a very striking manner by the following calculation:—

		Centesimally calculated formula.	Given mixture.
8 Eqs. of nitrate of potassa,..	808	.. 77·54	.. 78
6 Eqs. of sulphur, ...	96	.. 9·21	.. 10
23 Eqs. of charcoal—carbon,..	138	.. 13·25	.. 12
	1042	100·00	100

The analogy in both the foregoing instances is sufficient to show that the powder-maker has in compounding his mixtures an unfailing guide, by following which he cannot get far wrong. A little difference is occasioned in the foregoing, in the quantity of the calculated charcoal especially; but the explanation of the presence of hydrogen, which takes up such a large quantity of oxygen from the nitrate of potassa during the explosion of the powder, accounts for this. Indeed, were it not for this excess of hydrogen which makes up for the assumed amount of carbon in the charcoal, it would be difficult to reduce the quantities of real matter in the substances within the expression of a simple formula. Analyses show that the quantity of carbon in the charcoals which are usually incorporated, varies from sixty-eight to ninety per cent., and it is evident that when numerical quantities of the ingredients, such as expressed above for the manufacture of the powder, are strictly adhered to, serious differences occur in the quality of the article, according as the charcoal is more or less rich in carbon. To adhere, therefore, to the strict proportions indicated by the numbers laid down, and which assume that the materials are pure, it becomes absolutely necessary to determine the amount of carbon in the charcoal, and regulate the quantity according to such an estimation; otherwise it is not at all surprising that two powders prepared exactly according to any given recipe, but with different materials of unknown qualities, should have very unequal effect when exploded.

The following table shows the proportion of the ingredients used by the powder-makers of different nations :—

Countries.	Artillery Powder.			Musket Powder.			Sporting Powder.		
	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.	Saltpetre.	Sulphur.	Charcoal.
England—Government Mills, Waltham Abbey,	75·0	10·0	15·0	76·5	9·00	14·5	79·7	7·8	12·5
	75·0	8·0	17·0	78·0	9·25	12·75	78·0	8·5	13·5
	76·0	9·5	14·5	78·0	8·5	13·5	78·0	8·0	14·0
Austria,	70·0	16·0	17·0	72·0	16·0	17·0	....	....	....
	76·0	11·0	13·0	75·5	11·3	13·2	80·0	12·0	14·0
France,	75·0	12·5	12·5	75·0	12·5	12·5	78·0	10·0	12·0
United States,	75·0	12·5	12·5	....	....	....	....	....	....
Russia,	71·0	11·5	17·5	80·0	8·7	11·3	80·0	8·0	12·0
	75·0	10·0	15·0						
Prussia,	75·0	11·5	13·5	....	....	....	....	....	....
Spain,	76·5	10·8	12·7	....	....	....	....	....	....
Haarbourg,	72·0	14·0	14·0	....	....	....	....	....	...
Hanover,	71·2	10·8	18·0	....	....	....	....	....	....
Hesse—Grand Duchy,	74·4	10·6	15·0	73·7	10·7	15·6	....	....	....
" Electorate,	73·4	13·3	13·3	....	....	....	....	....	....
Holland,	70·0	14·0	16·0	....	....	....	....	....	....
Italy—Milan,	76·0	12·0	12·0	....	....	....	....	....	....
Portugal,	75·7	10·7	13·6	....	....	....	....	....	....
Saxony,	75·5	8·2	16·3	76·5	10·5	13·0	....	....	....
Sweden,	75·0	9·0	16·0	....	....	....	....	....	....
Wurtemburg,	75·0	12·0	13·0	74·5	10·7	14·8	....	....	....
Baden,	76·0	10·0	14·0	76·0	10·0	14·0	76·0	10·0	14·0
China,	61·5	15·5	23·0	....	....	....	....	....	....
	75·7	9·9	14·4	....	....	....	....	....	....

Several other proportions are in use in the countries specified above, which, to some extent, vary from those given. It is reasonable to suppose that in choosing the foregoing numbers, the manufacturers of the several countries mentioned have conscientiously selected the numbers given as affording the best results; still, as there seems to be no tabulation of the composition of the materials, more especially of the charcoal, the Editor believes that a considerable amount of empiricism must be connected with it; at all events, the variation in the proportions must be attributed to the inequalities in composition of the varieties used: for, had each sought the most appropriate mixture, and employed charcoal of a known per-centage of carbon, doubtless, instead of the many variations, one invariable proportion would be adhered to by all, and a close analogy in the explosive force of the powder could be calculated upon. The species of powder which is used for mining and similar purposes vary in composition from the kinds used for the military and for sporting; it has a much larger proportion of charcoal than the latter, and consequently it is less expensive. From the example given in the preceding of the parts of such powder centesimally, and the exposition of its decomposition by a rational formula, this is shown to be the case: besides, the products of the explosion contain, with carbonic acid, a large volume of carbonic oxide. As will be shown further on, the volume of gases which such a powder affords is larger than what results from the shooting powder; but still the propulsive effect is less than with the latter.

With reference to the study required to insure the production of the best possible compound, and to find a general recipe, VIOLETTE submits a suggestion to which the Editor subscribes, as it would contribute more than anything else to register the quality of the various powders and excite inquiry; namely, that a register of the propelling powder should be kept annually, and such submitted to a competent party for consideration. As to the indications in the targets, however, they are liable to be affected by the nature of the piece; and, in fact, the powder itself, when made from precisely the same ingredients by two neighbouring establishments, varies in some measure, in consequence of the dissimilar manipulations.

To ascertain how far the powders prepared from variable quantities of materials of the same centesimal composition differ in their balistic effect, VIOLETTE prepared a number of samples of fowling powder, each weighing about twenty kilogrammes, forty-four pounds, and submitted them to the test. The following are the results:—

No.	Per-centage composition of materials.			Amount of carbon in one hundred parts of charcoal.	Speed of the ball by the balistic pendulum.
	Saltpetre.	Sulphur.	Charcoal.		
1.	78	10	12	68	357
2.	72	9	19	68	350
3.	72	10	18	68	355
4.	71	10	19	68	361
5.	71	11	18	68	363
6.	71	9	20	68	370
7.	71	11	18	85	337

In this table No. 1 is the regular proportion, and the speed of the ball with such, supposing all the powder to be consumed, would be, according to the usual rule, three hundred and fifty metres. It is surprising to observe that No. 6 in the above collection, in which the saltpetre is diminished by eight parts, and the sulphur by one, and the charcoal increased by eight, is a superior powder to No. 1. No. 5 also constitutes a very good powder, but its quality would be considerably deteriorated by using, instead of the charcoal containing only sixty-eight per cent. of carbon, one yielding eighty-five per cent., as shown in the last. This forms a striking example of the way in which an inequality in the per-centage of carbon in the powder affects it.

The chief qualities which a good gunpowder ought to possess, are ready inflammability, complete decomposition of its constituents, the production of the largest possible volume of elastic gases, and finally, that of affording only the smallest possible amount of residue, and even that should be of such a nature as not to injure the gun.

Inflammability of Powder.—From what has been stated in the preceding pages relative to the degrees of heat required to decompose the constituents of powder, a good inference may be drawn as to the degree of heat at which powder will take fire.

However, if a small quantity of powder be slowly heated, and the temperature be gradually raised, it will be observed that the sulphur, which is the most inflammable constituent, will begin to burn with a blueish flame at 482°, or thereabouts; and the heat developed in this partial combustion brings the other constituents into that state at which the nitrate of potassa is decomposed by the charcoal, whilst the remainder of the sulphur adds to the effect by combining with the metal of the oxidising agent, thus—

$$KO, NO_5 + S + 3\,C = KS + 3\,CO_2 + N.$$

To ascertain whether the powders, as usually manufactured, actually do ignite at the burning point of sulphur, VIOLETTE made some examinations by placing portions of the powder to be tested on the surface of a bath of tin, in which the bulb of a thermometer was immersed, the whole being heated by a small carcel-lamp: the following results were obtained—

No.	Species of Powder.	Temperature which produced deflagration	
		Powder in angular grains	Pulverised powder.
1.	Blasting powder,	518°	[illegible]
2.	War "	528·5	510·5
3.	Sporting " fine,	536	5[illegible]4·8
4.	do. " extra-fine,	608	51[illegible]·0

Of these No. 1 was made with black charcoal, and No. 4 with brown or torrefied charcoal, the inflammability of which takes place at a much lower degree of heat than the first; still it is a matter of some surprise to find that the former, in the shape of powder, burns at a lower heat, excepting the variation in the quantity of sulphur present in them may influence the deflagration. This element is present in the four samples in the following ratio, namely, 20, 12·5, 10, and 9 per cent.; the most combustible of the powders having the largest amount of sulphur, which, of all the elements, is the most ready to enter into ignition. It may likewise be remarked that the size of the grain influences, in some measure, the temperature at which the powder burns.

Balistic or Propulsive Effect of Gunpowder.—The force with which a ball is projected, or a rock fractured, is, as may be easily understood, in proportion to the volume of gases which is produced when gunpowder or any other modification of this article is deflagrated. In case of gunpowder, these gases are principally carbonic acid and nitrogen; and where mining powder is operated upon, carbonic acid is likewise a product. But besides these it is found that small quantities of many other products are invariably formed, among which may be mentioned carbonic oxide, sulphurous acid, sulphide of hydrogen, bisulphide of carbon, carbonate of potassa, cyanide, and sulphocyanide of potassium and aqueous vapor. The most important products of a careful and complete combustion, on a small scale, of powder of the above composition, have, however, been found to correspond pretty closely to the above theoretical expression.

The gases disengaged in the combustion of this powder, would comprise, at 32°, a volume three hundred and twenty-nine times as great as that occupied by the powder. The force exerted by the evolution of these gases is, however, mainly dependent upon their enormous expansion at the instant of the explosion, by the heat evolved in the action; for it is calculated that one volume of powder of the above composition yields, at the moment of ignition, at least two thousand times its volume of gas.

If gunpowder contain more carbon in proportion to the nitrate of potassa than the quantity above stated, a proportionate amount of *carbonic oxide* is produced in its explosion; thus if *six* instead of *three* equivalents of carbon be employed to one equivalent of saltpetre, the whole of the oxygen contained in the latter would theoretically be eliminated as carbonic oxide on the decomposition of the powder, as the following equation shows:—

$$\underbrace{KO, NO_5}_{\text{Nitrate of Potassa.}} + \underbrace{C_6}_{\text{Carbon.}} + \underbrace{S}_{\text{Sulphur.}} = \underbrace{K\,S}_{\text{Sulphide of Potassium.}} +$$

$$\underbrace{6\,CO}_{\text{Carbonic Oxide.}} - \underbrace{N}_{\text{Nitrogen.}}$$

Now, since the space occupied by equal equivalents of carbonic oxide and carbonic acid is the same, it is evident that a much larger volume of gas would be evolved—calculated for a temperature of 32°, and ordinary barometric pressure—from the gunpowder which contained the larger amount of charcoal. But it must be borne in mind that the amount of heat disengaged in the production of carbonic oxide is far less than that generated when carbonic acid is produced, and that consequently the powder which contains the minimum quantity of charcoal will yield, *at the instant of explosion*, by far the greatest bulk of gas. That this expansion of the gas by heat is of the utmost importance, is very evident from what has been already stated. The fact that the temperature evolved by the combustion of gunpowder, estimated at 2192°, has been found to be sufficiently intense to fuse gold, silver, and other metals, and that the expansion of gases increases greatly with an augmentation of temperature—two hundred volumes of gas raised to 2428° occupying the same bulk as three hundred volumes, which are only heated to 1466·6°—render the value of a slight elevation of temperature at the moment of explosion still more apparent.

As it is difficult, nay impossible, under ordinary circumstances, to gain a knowledge of the quality of powder by any method involving the necessity of measuring the gases and caloric evolved, a more direct course of experiments is resorted to. This method was founded by PROUST partly upon the duration of the combustion, coupled with the volume of gases which were eliminated. The methods of operations employed were the same as those already described with regard to the estimation of the time required to deflagrate charcoal and nitre, *et cetera*. The following were his results :—

No.	Saltpetre.	Sulphur.	Charcoal.	Time of combustion in seconds.	Products in gas in cubic inches.
1.	60	10	15	6	91
2.	60	10	12	6	91
3.	60	10	10	6	91
4.	60	10	$8\frac{4}{7}$	7	88

It is presumed that these determinations, however, leave much to be required, not only in the accuracy of the determinations, but with respect to practical application.

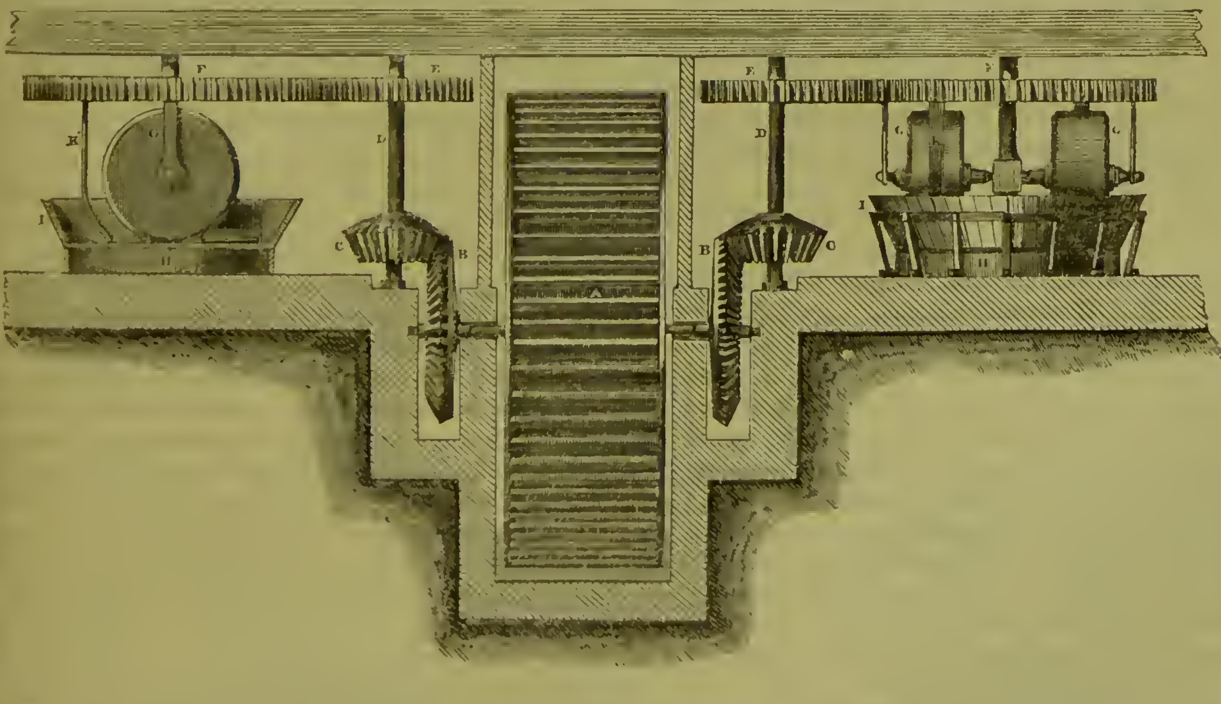
TOMLINSON adopted another method, which, on the whole, is more applicable to practice—namely, the determination of the altitude of rockets, and which he describes as being less liable to disturbances from collateral causes than any practice with pieces of ordnance. The rockets were of compound dimensions, and were all made with the same proportions and driven with the same hand, so as to insure all possible uniformity; the only variation being in the nature of the charcoal. The vertical elevations were taken by two quadrants at the same time, and all the flights that deviated from the perpendicular were rejected. The mean vertical ascent made with a great number of these, in which the charcoal was from the willow, alder, and dogwood, was four hundred and eighty yards; but between these three charcoals the difference was so great as to give various results, which may be represented by the following numbers :—

Dogwood charcoal,	515, 550, 525
Willow "	470, 480, 490
Alder "	455, 460, 470

To the methods in use, and recognized by the military and powder manufacturers generally, reference will be made further on.

Upon comparing the composition of the powders prepared in different countries for fire-arms, they will be found to agree more or less closely with the centesimal composition as above expressed. It must be remembered, however, that the proportions have been arrived at by experience, in most cases long before any theory concerning the chemical composition or action of powder was advanced. In some cases the deviations from the theoretical numbers may be readily ex-

Fig. 248



plained. Thus in the manufacture of the Waltham Abbey powder, a slight excess of charcoal is always employed in order to allow for the small quantity of inorganic matter always associated with carbon in that form; while the proportion of sulphur is reduced as much as is compatible with the production of a strong powder, in consequence of the injurious action of that substance, and even of sulphides in the presence of moisture, upon metal.—*Abel and Bloxam.*

MANUFACTURE.—The merely mechanical part of the manufacture of gunpowder is essentially the same in principle, and differs only to an immaterial extent in detail, whether in the various gunpowder mills in Great Britain, or in those of her continental neighbors. The Editor will trace the method of manufacturing gunpowder as it is employed at the Government Mills, Waltham Abbey:—

In the first place, it may be stated that water is the motive power in most gunpowder mills; the necessity of the presence of fire when steam is made use of is attended with so much danger, that this agent has not yet been introduced for the purpose.

The gunpowder mill is represented in Fig. 248, where A is the water-wheel; B B, two vertical bevel wheels fixed upon the axis of the great wheel, and working into C C, which turn the shafts, D D; E E are two horizontal spur-wheels, fixed to the upper part of D D, and driving the large wheels, F F. To the shafts of these latter are fixed the runners, G G, which traverse the bed-stone, H H; I I are the curbs surrounding the bed-stone to prevent the powder from falling off; K is the scraper.—*Ure.*

The materials, having been pulverized in the mill, are apportioned out, the following being the proportions at Waltham Abbey:—

	Pounds.	Ounces.	Drachms.
Saltpetre,	31	8	0
Charcoal,	6	4	13
Sulphur,	4	3	3
	42	0	0

This quantity of the ingredients, termed a *charge*, is placed in the mixing apparatus, which consists of a wooden cylinder traversed in its centre by an octagonal shaft provided with several fan-like arms. Both the shaft and cylinder are kept in motion, but in different directions. This latter arrangement so facilitates the commingling, that the homogeneous powder is ready for removal and further manipulation in from five to ten minutes, when it is transferred to bags which are pressed, and the mouths of which are firmly secured, in order to prevent the disunion or separation of the ingredients in the order of their density, during the transport to the incorporating mill. It is evident that if the charges were too lightly packed, the ingredients would be liable to be separated in a greater or less degree, the saltpetre finding its way to the bottom, while the sulphur and charcoal would form layers above; the latter, from its light, pulverulent state escaping, in the form of dust, between the fibres of the cloth of which the bag is formed.

The next process is the *incorporation.* The mixture is spread out upon the bed of the mill, distilled water is added to insure the intimate cohesion of the particles—the amount of water required varying much according to the temperature and other atmospheric conditions, as also in proportion to the degree of comminution of the constituents—and the whole is again submitted to the action of the mill, to insure the uniform pressure and bruising of the rollers; but in this case the motion is less rapid than during the grinding of the ingredients. A great degree of caution must be exercised to prevent the intervention of any hard or silicious matters. The requisite amount of moisture must be maintained during the operation, and for this purpose water is slowly added at suitable intervals, till the incorporation is complete, which is generally the case at the expiration of from three to four hours.

The homogeneous compound has now the properties of gunpowder; it indurates in a very short period, forming hard cakes, which should possess a dark greyish-black hue, and free from specks of any kind; it is now termed *mill-cake.* When this has lost much of its moisture, but before it becomes completely dry, it is passed between corrugated or channeled cylinders, termed the *breaking-down mill*, and is then submitted between copper plates, placed in strong boxes, to hydraulic pressure of about one hundred and twenty tons per square foot, after which it is known as *press-cake*: it is now greatly altered in appearance, and apparently resembles slate, being in dense blackish cakes, about half an inch in thickness. This powerful pressure is productive of several advantages:—

1. The powder has a greatly augmented density, and a given quantity of it will evolve, on combustion, a far larger volume of gas, than an equal bulk of powder which has only received the pressure of the incorporating mill.

2. From the increased hardness of the powder, it better resists atmospheric action; and besides this, it is not so liable to loss from *dusting*, caused by friction, during its transport.

The powder has now to be granulated. The machine employed for this purpose at Waltham Abbey consists of a pair of metal cylinders, provided with large teeth, upon which, while in revolution, the press-cake is allowed to fall in fragments; by this means it is reduced to grains of various sizes. As these pass from the cylinders or rollers, they are submitted successively to the action of three sieves of graduated fineness, placed one over the other, and jolting or working continually backward and forward. The powder retained by the first sieve is subjected to the action of a second pair of rollers with finer teeth, whence it again passes to, and is sifted by, the upper screen. The portions still too coarse to pass through, are reduced by a third still finer set of rollers. The powder manufactured at Waltham Abbey is distinguished as L. G., or *large-grain*, F. G., or *fine-grain*, and *meal-powder*, or dust. The first variety is retained by the second sieve; the lowest sieve reserves the fine grain; the dust, or meal-powder, collects beneath. Each kind is collected, as it falls from the screen, in boxes running on wheels and rails.

Various other contrivances belong to this effective machine to obviate the necessity for the attendance of workmen, and, consequently, to prevent their injury should any accident occur.

The granulated powder is next freed from dust by running it through *reels*, similar to the bolter employed in dressing flour—encased in boxes, and covered with canvas or with silk, of about fifty-six meshes to the inch, according as large or fine-grain powder is introduced.

The finest powder is now *glazed* by subjecting it, in a slightly moist state, to rotary motion in barrels or drums, similar to the mixing machine already noticed. The velocity of rotation must be just sufficient to cause the grains only to roll over each other slowly, and thus become polished by attrition. Blasting-powder is occasionally glazed with graphite.

The gunpowder is finally dried, which is now generally done by means of steam-heat; sometimes it is effected by transmitting a current of air, previously heated in another chamber to from 130° to 150°, over the powder placed on canvas shelves.

On the Continent, the powder is chiefly granulated in drum-sieves, generally made of perforated parchment skins or of copper, fitting into each other, and fixed in a frame to which rotary motion is communicated by proper machinery. On the uppermost of these is placed a circular piece of heavy wood, as lignum vitæ, sometimes loaded with lead, which traversing the surface of the sieve, gradually reduces the fragments of the powder, until they are sufficiently fine to pass through the perforations or meshes.

PROPERTIES.—Good powder, according to ABEL and BLOXAM, should be perfectly uniform in texture; light specks or glittering points indicate an incomplete mixture. The grains should be sufficiently hard not to be easily crushed between the fingers, and not to soil these or a piece of paper by mere contact. Gunpowder should burn rapidly, leaving only a *very slight* residue. If inflamed upon white paper, it should blacken it but slightly, and should on no account set fire to it. Powder is inflamed by any burning substance, by an electric spark, by red-hot metal, or by violent concussion. It does not ignite, however, by exposure to a temperature below redness. If subjected in an atmosphere of hydrogen or carbonic acid to a gradual increase of temperature, the sulphur may be completely separated, subliming upon the cool portion of the vessel.

It has been proved that powder may be inflamed, not only by the concussion of hard bodies, but by that of comparatively soft ones, provided it be sufficiently powerful. Experiment has shown that powder placed upon lead, or even upon wood, may be ignited by the shock of a leaden bullet fired at it.

No doubt the inflammability of a powder is greatly influenced by its physical state. A fine-grain powder will burn much more rapidly than powder of a larger grain. The greater the density, the more gradual is its combustion. Angular powder will burn more speedily than the round-grained, and the inflammability of powder is not only retarded by the presence of moisture, but also by the glazing.

Powder in which the theoretical proportions are exact, and in the manufacture of which a very inflammable charcoal has been used, the ingredients having been mixed without the application of very great pressure, will undergo, when ignited, an almost instantaneous decomposition. Such a composition, in many respects, resembles the fulminates; the strain which it exerts upon the fire-arm is far too powerful; hence it is not so generally applicable as a more gradually disintegrating mixture.

Gunpowder always attracts more or less moisture, since charcoal, however dense, absorbs humidity from the air; though, of course, the hygroscopic property of powder is considerably increased by the use of porous charcoal in its manufacture, or by the presence of any considerable quantity of powder-dust. Powder, manufactured with perfectly pure nitrate of potassa, is found, if preserved in dry stores, to absorb about 0·5 per cent. of moisture; the amount naturally increases considerably if it is kept in a damp situation. Fine-grain powder is generally found to absorb moisture more rapidly than the large-grained.

The amount of ash left upon the ignition of gunpowder varies according to the purity of its ingredients, the proportions employed, and, more particularly, the nature of the charcoal used. Its gradual accumulation in a fire-arm is a source of great inconvenience, since it soon renders it foul and difficult to charge, thus limiting the number of rounds that can be fired in rapid succession, without cleaning out the instrument. This *fouling*, as it is termed, is avoided to some extent by the use of a small quantity of some fatty substance, which lubricates the barrel, and, by preventing the adhesion of the ash, promotes its expulsion by the gases as they make their escape.—*Abel and Bloxam.*

BISHOP affirms that gunpowder explodes exactly at the temperature of 600°. When exposed to a heat of 500°, its nature becomes totally changed; not only is the whole of the moisture expelled, but the saltpetre and sulphur are reduced to the fluid state. The powder on cooling is found to have changed from blackish-grey to an intense black; the grain has become extremely indurated, and by exposure even to very moist air, it then suffers no alteration by imbibing moisture.

The specific gravity of gunpowder, according to Dr. URE, as taken by him with five different kinds in oil of turpentine, varied from 1·793 to 1·80.

ANALYSIS.—The following is the ordinary method of analysing gunpowder:—

The water is first estimated by submitting a small portion, say three or four grammes of the sample to be examined, to a temperature of 212°, in a water-bath, until it ceases to lose weight. Some chemists prefer placing a known quantity over sulphuric acid *in vacuo*, but this method takes much more time, and the former is sufficiently accurate for all ordinary purposes. The loss after drying shows the amount of moisture in the sample, from which the per-centage may be readily calculated.

It may be well for the Editor to remark here, that the quantity of water should be *a mere trace*, if any. If it is found to contain several per cent. of water, it may be rendered again perfectly good by careful exsiccation.

The next step is the determination of the nitrate of potassa, which is effected by boiling the powder in which the humidity has been determined, in about six times its weight of water; the residuum is then carefully collected on a tared filter, washed with tepid water until a few drops of the filtrate when evaporated upon platinum foil give no residue; the insoluble matter upon the filter being then desiccated at 212°, and weighed, the loss will indicate the amount of nitrate of potassa. The saltpetre may also be determined by evaporating to dryness the filtrate obtained as above, fusing the residuum at a low temperature, and then ascertaining its weight. Both these methods may be employed, the one thus furnishing a check upon the other.

Should the saltpetre contain chloride of sodium, as it ordinarily does, the amount of it may be determined as follows:—The dry and weighed residuum, procured as just described, is redissolved in water, and a little nitric acid and a weak solution of nitrate of silver added, when, if chlorides are present, a curdy precipitate of chloride of silver occurs; this is collected on a filter, edulcorated, dried, fused with great care in a porcelain crucible, and weighed. One gramme of the chloride of silver represents ·407 chloride of sodium, or ·247 of chlorine.

The amount of sulphur and carbon, respectively, may be ascertained by various methods.

One of these, devised by Gay-Lussac, consists in igniting in a platinum crucible a known quantity—say one gramme—of the gunpowder, with the same weight of carbonate of potassa and of nitrate of potassa, and four times the quantity of common salt; by this means the sulphur is oxidised into sulphuric acid, and may be determined as under:—The fused mass, which should be perfectly white, is dissolved in water, and acidified by means of hydrochloric acid. The solution is next filtered, and chloride of barium added so long as a deposit is occasioned. After some time, when the precipitate has subsided, the whole is filtered, and the sulphate of baryta aspersed with hot water, until sulphuric acid causes no turbidness in a portion of the washings. The precipitate is next dried, and then, as much of it as is possible being detached from the filter paper, the latter is burned in a platinum crucible until the whole of its carbonaceous matter is destroyed; the former introduced, heated to redness, and weighed. Each 116·5 parts of sulphate of baryta represent forty-nine parts of monohydrated sulphuric acid, and consequently sixteen of sulphur.

The per centage of moisture, nitrate of potassa, and sulphur being calculated, the difference indicates the amount of carbon.

White Gunpowder.—Augendre has described a new kind of gunpowder, consisting of one part of ferrocyanide of potassium, one part of white sugar, and two parts of chlorate of potassa. These are reduced to powder separately, and are then mixed with the hand. In experiments with small quantities, they may be pounded together in an agate mortar. Not the least fear need be entertained of the effects of the most powerful friction. In preparing it on a larger scale, the mixture is moistened with two or three per cent. of water, and triturated in a bronze mortar with a wooden pestle; fifteen minutes' pounding suffices for small quantities, as the ingredients do not require such intimate admixture as in the preparation of ordinary gunpowder. The powder is granulated in the usual way, and dried in the air.

Gunpowder thus prepared is white; fires with the greatest ease, both in the granular state, and in that of an impalpable powder, by contact with an incandescent body; the flame with which it burns is greater than that of ordinary powder, and it leaves less residue. As taken from the mortar it is perfectly inflammable, so that there never need be any apprehension of its missing fire. It must be exceedingly dry for a violent blow of iron to explode it; friction between two polished bodies never produces this effect, nor does striking wood upon wood, or wood upon metal. It is formed of substances, the composition of which is well determined and fixed, and it can, therefore, always be obtained of the same strength. The materials are unalterable by the action of dry or humid air, so that they can be kept for any length of time, which cannot be done with the charcoal used for the ordinary article. The manufacture requiring less time, a fortress might, in case of necessity, be provided with the several constituents in powder, and the mixture made when required, by which means the danger attendant upon large deposits of gunpowder would be avoided. The force is much greater, so that there is space for a larger number of charges in the artillery caissons. The dust having the same effect as the grain, each constituent might separately be reduced to a very fine powder, and the whole commingled in a leather barrel.

But though possessed of all these superiorities over common gunpowder, it is not free from serious disadvantages, one of which is, that it oxidises iron barrels very much, and its use is consequently limited to bronze ones, and to the filling of hollow projectiles. It is more easily inflamed than common gunpowder, but not so readily as the other compounds of chlorate of potassa which have been prepared for the same purposes.

Augendre directs attention to the circumstance, readily conceivable from the behavior of chlorate of potassa towards several other substances, that the greatest care should be taken to avoid introducing into the mixture any charcoal or sulphur, or mixing with it any ordinary gunpowder.

The proving of gunpowder, and many other subjects connected with the present article, are not of a sufficiently chemical nature to be treated of here.

Statistics.—Gunpowder is always packed in strong oak barrels, containing from eight to one hundred pounds each, the latter being the maximum weight allowed by Government to be contained in a single package. When for sporting purposes, it is in canisters and strong papers.

Owing to gunpowder being entirely free from duty, the returns of the Board of Trade can scarcely be expected to give even an approximation to the amount of imports and exports. Indeed, the import returns during the years 1850 to 1853 inclusive are entirely blank, while, for 1854, they are registered as one hundredweight, and in 1855, 11,851 hundredweights. During the years 1850-55 inclusive, there were no returns of exports.

GUTTA-PERCHA.—This valuable substance, the name of which is the same in all languages, and which was unknown in Europe previous to the year 1843, is the inspissated juice of a tree which grows in the Malayan forests and the islands of the Eastern Archipelago. In its origin, character, and composition, it is analogous to caoutchouc, but wants the peculiar elasticity of that substance; on the other hand, it possesses special and distinct properties, which render it applicable to an extraordinary variety of important uses, and which, within the short time that has elapsed since its introduction into Europe, have given a remarkable development to its manufacture.

It may not be out of place, even in a scientific work, to correct an erroneous mode of pronouncing the name of this substance, which has become very general. The name is a pure Malayan one, and not Latin, as might be supposed from a mere coincidence in the spelling—*gutta* meaning in the Malay language the gum or concrete juice of a plant, and *percha* the particular tree from which the juice is procured. Dr. MONTGOMERIE, its discoverer, states that the *ch* is not pronounced hard like a *k*, but like the *ch* in the English name of the fish *perch;* and that if a European were to inquire of a Malay for gutta *perka*, he would be told the thing was unknown, when perhaps plenty of the gutta-percha might be procurable by pronouncing the name properly. He adds, that had he thought there was a probability of the name being mispronounced, he might have used the uncouth orthography *pertsha*, but then it would have run the risk of being taken for a Russian or Polish appellation.

HISTORICAL NOTICE.—It appears that this substance, though only of recent introduction into commerce, was brought into England in the days of TRADESCANT, as a curious product, under the name of *mazer wood;* and subsequently it was frequently brought from China and other parts of the East, under the designation of india-rubber, in the form of elastic sticks, whips, and other trifling articles. The products of the East Indies, shown by the Honourable East India Company at the Great Exhibition, proved that the natives of the country in which the gutta-percha tree grows, knew also how to appropriate it to the manufacture of different kinds of vases, and that European industry and the wants of an advanced civilization have only developed its application to a greater variety of uses than were known or required in the countries to which it belongs.

The merit of first appreciating its value and making it known in Europe, is claimed by two individuals, who seem to have endeavored about the same time, and quite independently of each other, to bring it into public notice, namely, Dr. WILLIAM MONTGOMERIE, a Scotchman, for some years assistant-surgeon to the Residency at Singapore, on the Malay peninsula; and Sir JOZE D'ALMEIDA, who had been for many years resident in the same settlement. This last-named gentleman came over to England in the beginning of the year 1843, bringing several samples of the gutta-percha with him; and, among other channels of communication with the scientific world, had the honor of presenting specimens to the Royal Asiatic Society, for which he received their letter of acknowledgment and thanks. On the whole, however, the merit of priority of discovery seems, by general assent, to be assigned to Dr. MONTGOMERIE, who, in point of fact, was not only the first European who discovered the value of the product, but the first who exerted himself actively and successfully to bring it into general use. Before the attention of this gentleman was directed to it, it was not only quite unknown to Europeans in general, but was known as an article of value only to a few of the inhabitants even of those localities in which it is produced, and was applied by the natives to very trifling uses; being chiefly employed to make handles for *parangs* or wood-choppers, as a substitute for wood or buffalo-horn.

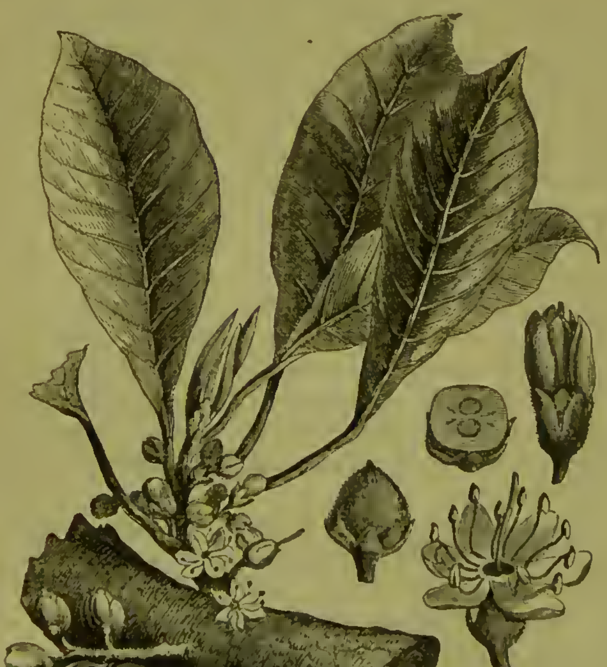
The valuable qualities of the substance were no sooner publicly announced than it came into general demand. The immediate effect of its discovery may be compared to that of the gold-fields in California and Australia; and perhaps no substance except the precious metals has been more eagerly sought after or more highly appreciated. Its singular adaptation for an infinite variety of purposes was quickly recognized, and an extensive trade in it sprang up almost immediately. In the year 1844, previous to which its very name was unknown to European commerce, two hundredweight of it were shipped experimentally from Singapore. In 1845 the exportation of it from that port rose to one hundred and sixty-nine piculs—a picul being equivalent to 133·3 pounds; in 1846, to five thousand three hundred and sixty-four piculs; in 1847, to nine thousand two hundred and ninety-six; in 1848, to twelve thousand. In the first four and a half years of the trade, twenty-one thousand five hundred and ninety eight piculs of gutta-percha, valued at two hundred and seventy-four thousand one hundred and ninety dollars, were shipped at Singapore; the whole of which was sent to England, with the exception of fifteen piculs to Mauritius, four hundred and seventy to the Continent of Europe, and nine hundred and twenty-two to the United States.

The knowledge of the article, stirring the avidity of gatherers, gradually spread from Singapore, Northward, as far as Penang; Southward, along the East coast of Sumatra to Java; Eastward, to Borneo, where it was found not only at Sarawak, but also at Bruné and Pontianak on the West coast, and at Reti and Passir on the East.

This eager demand for the precious gum, animated by the thirst for immediate gain, was productive of a reckless destruction of the valuable trees that produced it. Instead of simply tapping the trees to obtain the juice, as is practised in the case of caoutchouc, the monarchs of the forest were felled to the ground; a magnificent tree of fifty or one hundred years' growth was cut down, the bark stripped off, and the milky juice collected and poured into a trough formed by the hollow stem of the plantain leaf; and some idea may be formed of the havoc thus made to procure the large supplies which were imported into Singapore, when it is stated, that on an average not more than twenty or thirty pounds were procured from one tree. The result was, that in the course of three and a half years, two hundred and seventy thousand trees were felled, in order to get at the gum. It was, therefore, apprehended that the tree, although at first sufficiently plentiful, would soon become difficult to be procured; and this would undoubtedly have been the case, had not the Gutta Percha Company, subsequently formed in England, acted with a wise precaution, and embarked a considerable capital in seeking to promote the tapping, instead of the felling of the trees.

THE GUTTA-PERCHA TREE.—For some years after the introduction of gutta-percha, the character of the tree which produces it remained a mystery. At length from specimens which were sent home by Dr. OXLEY, in 1847, Sir W. J. HOOKER was enabled to refer the plant to Dr. WRIGHT's new genus of *sapotaceæ*, called by him *isonandra;* and accordingly he proposed to designate the gutta-percha plant *isonandra gutta*—the name by which it is now known. The tree is from forty to seventy feet high, and from two to four or even six feet in diameter. It is found all up the Malayan peninsula, as far as Penang, and its favorite localities are the alluvial tracts on the foot of hills, where it forms the principal portion of the jungle. In its general aspect, says Dr. OXLEY, it resembles the Durian—*Durio Zibethmus*, Linnæus—so much so as to strike the most superficial observer. The trunk is straight; the leaves alternate; their upper surface of a pale green, and their under covered with a close, short, reddish-brown hair. The flowers are axillary, from one to three in the axils, supported on short curved pedicels, and numerous along the extremities of the branches. The wood is described by HOOKER as peculiarly soft, fibrous, and spongy, pale-colored, and traversed by longitudinal receptacles of reservoirs filled with the gum, forming ebony-black lines. Fig. 249 is a portion of a branch of the gutta-percha tree, exhibiting also the leaves, flowers, and fruit.

Fig. 249.



There is no doubt that these are the characteristics of the tree from which the substance known as gutta-percha is obtained; but SEEMAN states that the gum termed by the Malays gutta-percha, is not the produce of the *isonandra gutta*, but that of a botanically-unknown tree, a species of *ficus*, and that the substance which has been improperly termed gutta-percha by Dr. MONTGOMERIE, and must now continue to be so called, is really the *gutta-taban*. It must ever be an object of regret, he remarks, that on the first introduction of the *taban gum*, its real name was not promulgated. The name, however, is now fixed beyond recall; and, to prevent misunderstanding, the reader has only to bear in mind that the substance known in Europe as *gutta-percha*, though stated by SEEMAN to be the *gutta-taban* of the Malays, is really the produce of *isonandra gutta* above-described.

EXTRACTION AND INSPISSATION OF THE GUM.—The sap or gutta circulates between the bark and body, in vessels, of which the course is well marked by black longitudinal lines upon the wood. To obtain the juice, it was formerly the practice, as already stated, to cut down the full-grown tree close to the root; rings were then made in the bark at distances of about twelve to eighteen inches apart, and a cocoa-nut shell, spathe of a palm, or such like receptacle, was placed under the fallen trunk, to receive the milky sap that immediately exuded upon every fresh incision. The quantity of gutta obtained from each tree so destroyed varied from five to twenty catties; so that taking the average of ten catties, it would require the destruction of ten trees to produce one picul, or one hundred and thirty-five pounds of gutta.

Fortunately, experience has now taught the natives that the milky juice may be collected by cutting notches here and there in the trunk of the living tree, and that in this way it may be preserved for future tappings. This more economical method is rapidly gaining ground: and, considering the vast extent of territory occupied by the tree in its several varieties, and that European industry is now so deeply interested in its culture and preservation, there is little danger of the supply becoming exhausted.

The sap coagulates in a few minutes after it is collected; but before the crude gum becomes quite hard, it is kneaded by hand into compact oblong masses, from seven to twelve inches in length, by four or five in thickness. This part of the work is mostly performed by women, as represented in the annexed engraving—Fig. 250—which exhibits not only the ordinary appearance of the native Malays, but the character of the internal forest scenery of the tropical regions which they inhabit.

Dr. OXLEY's account differs somewhat from the preceding. He states that the sap, instead of coagulating and being made up into blocks on the spot, is collected in bamboos, taken by the natives to their houses, and boiled, in order to drive off the watery particles and inspissate it to the consistence it finally assumes. He adds, however, that although the process of boiling appears necessary when the gutta is collected in large quantities; yet, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article. The apparent discrepancy between the two statements may perhaps be explained by the fact, that Dr. OXLEY'S account was written when the trees were uniformly felled to procure the juice, and when the latter was, therefore, collected in considerable quantities at a time, which rendered boiling necessary; whereas, when slowly collected in smaller portions from a number of living trees, the watery ingredient will evaporate as the juice exudes, and, with the assistance of kneading or moulding by the hand, that consolidation will take place to which Dr. OXLEY alludes as occurring in the case of small quantities.

Fig. 250.

PROPERTIES.—Gutta-percha, when quite pure, is of a greyish-white, but, as brought to market, it is more ordinarily found of a reddish-brown hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which tinge it. It may be readily obtained in a pure state by dissolving the crude gutta in sulphide of carbon, filtering the turbid and brown solution under a bell-glass, and evaporating the filtrate by simple exposure to the air in a flat porcelain dish. After desiccation, the thin plate or cake of purified gutta is easily detached from the vessel by covering it for a few minutes with cold water, which destroys the adhesion. Nearly the whole of the extraneous tinctorial matter remains on the filter, with a portion of the undissolved substance.

Thus februated, the gutta is almost white, is semi-translucent in thin leaves, but opaque in thicker plates; it is greasy to the touch, and has a peculiar leathery smell, somewhat similar to that of india-rubber. Its specific gravity, as determined by Dr. A. ADRIANI, was 0·999 at 68°, when subjected to the action of an air-pump to remove the adhering water-bubbles; without this precaution, it was only 0·728. A specimen of gutta-percha mechanically purified, and shaped in cakes, was found to have a specific gravity of 0·966°. The average density of the commercial article is 0·975°. The great variations in its density under different treatment imply a peculiar porosity in its structure, which was experimentally verified by PAYEN. Having placed a drop of its solution in bisulphide of carbon on a slip of glass, and allowed it to evaporate in the manner above-described, so as to obtain a thin film of the substance in a state of purity, he observed with the microscope numerous small holes or cavities, which were rendered still more visible by a drop of water; the liquid gradually insinuating itself, and rendering the film more opaque, while the cavities were observed, by means of the lens, to be enlarged. Similar results were obtained by keeping immersed in water for a considerable time, thin transparent laminæ, obtained by the evaporation by heat of a solution of gutta-percha.

It was these observations which led this eminent chemist to conclude that the common commercial gutta-percha, retaining, in consequence of its porosity, a great many minute particles of air, owed to this circumstance its appearance of possessing a less density than that of water. In fact, on stretching gutta-percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fell to the bottom of the vessel—some immediately, others absorbing a certain quantity of moisture. The same result was also obtained by keeping very thin leaves of gutta-percha, prepared by different methods, immersed in water deprived of air; their pores being gradually filled with the liquid, they became heavier than it, and then ceased to float. Gutta-percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porosity of gutta-percha, which allows a slow transudation of liquids through its mass, is the principal drawback to its use when formed into bottles or other vessels for holding chemical fluids. This porous structure becomes changed into a fibrous texture when it is drawn out so as to double its length; then, retaining little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Gutta-percha is a bad conductor of both electricity and heat. When rubbed it becomes negatively electric, and if dry, is an insulator equal in efficiency to shell-lac. Hence, among many other important applications, which will be noticed afterwards, its extensive employment in the covering of wires for the submarine telegraph.

But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of heat upon it, applied either directly, or through the medium of boiling water. At ordinary temperatures it is a tough inelastic substance, and cold water has no effect upon it; from 32° to 77° it possesses about as much tenacity as thick leather, with rather less flexibility; towards 120° it softens, and becomes sensibly doughy, although still very tough; and when raised above 150°, either by exposing it to the fire or by immersing it in hot water, it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. Its ductility is such that, at a temperature of from 150° to 240°, it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess, at any temperature, the peculiar elastic extensibility which characterizes caoutchouc. When cold, it again becomes hard, and possessed of extraordinary tenacity.

It melts at 248°, and may be made to boil without acquiring a sensible color; the transparent fluid gives abundant vapors, which are condensable into a nearly colorless oily liquid. The portions last distilled have a brownish-orange hue, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel. Heated beyond this point, it is decomposed, yielding inflammable products; a strip of it cut off burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing-wax, which in its combustion it very much resembles.

Common gutta-percha is perfectly insoluble in water *at any temperature;* it effectually resists damp, and hence its valuable applications as a waterproofing material, and as a substitute for leather in soling boots and shoes. It likewise withstands the various influences which excite fermentation, but experiences a sort of doughy fusion when exposed to the direct action of the solar rays in summer. Soda and potassa, even when caustic and concentrated, ammonia, saline solutions of all kinds, water containing carbonic acid, the various vegetal and mineral acids, do not act upon it. It is not affected by fermented liquors, such as wines, beer, *et cetera;* even alcohol scarcely dissolves a trace of it. Olive-oil has no action upon it when cold, but when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Concentrated nitric acid attacks gutta-percha rapidly with effervescence, and an abundant evolution of fumes of nitrous acid; the gutta is disintegrated, and colored of a brownish-orange red; it becomes doughy, and afterwards solidifies by degrees, but remains friable. Concentrated sulphuric acid produces the same effect more gradually, rendering it brown, and causing its disintegration, with a sensible evolution of sulphurous acid. MILLER affirms that hydrochloric and dilute hydrofluoric acids have no action upon it; hence it is employed in the preparation of bottles and vessels used for containing these liquids; but PAYEN states that hydrochloric acid, in its saturated solution in water at a temperature of 68°, attacks gutta-percha slowly, and gives it a more or less deep-brown color, at length rendering it brittle.

The same chemist remarks that, in the cold, and even by heat, not more than 0·15 to 0·22 of the gutta-percha is dissolved by anhydrous alcohol or ether; but ARPPE states that thirteen per cent. of gutta-percha is dissolved by alcohol, and that, separated from mechanical admixtures, it is *soluble in ether which is free from alcohol,* whereas, *if it has been previously treated with alcohol, it does not dissolve in ether.* This observation, which seems to have been overlooked by M. PAYEN and other chemists, has an important bearing on the analysis of gutta-percha.

Benzol and oil of turpentine dissolve gutta-percha partially when cold, but almost completely by heat. One part of the gutta requires for its solution from four to six parts of oil of turpentine. Bisulphide of carbon and chloroform dissolve it cold, and by either of these solvents it may be obtained pure in the manner already described.

ELEMENTARY COMPOSITION.—Gutta-percha is, like caoutchouc, a carbide of hydrogen, and nearly isomeric with that substance, as the following analyses will show:—

	Gutta-percha.		Caoutchouc.
Carbon,	86·36	....	87·2
Hydrogen,	12·15	....	12·8
Oxygen,	1·49	....	—
	100·00		100·0

It is a question indeed whether the elementary composition of the two substances is not precisely the same, the small quantity of oxygen detected by Dr. MACLAGAN in gutta-percha being probably derived from the air during the process of purification. Its acknowledged porosity, and the difference in its specific gravity under different conditions, are facts which afford a strong presumption in favor of this view.

But like other isomeric substances, gutta-percha and caoutchouc, though strikingly similar in many of their properties, and more especially in their resistance to the action of most chemical agents, differ considerably in other respects, and this must be attributed to the different grouping of their elementary constituents, if not to the actual presence of oxygen as one of the essential ingredients of gutta-percha.

Professor PAGE states that gutta-percha, when rolled into thin sheets or drawn into ropes, comports itself like a fibrous substance, which is not the case with caoutchouc. A strip cut from a thin sheet of gutta-percha may be stretched considerably in one direction, that is, in a line with the fibre, but any attempt to stretch it across this is followed at once by a rupture. It is not so with a sheet of caoutchouc, which will stretch *equally well in all directions.* On examination of sheets of these two substances—so far believed to be *isomerical*—a marked difference of texture is at once perceived. The caoutchouc gives little or no change of color, while the gutta-percha exhibits a beautiful spectacle. It appears to be built up of prisms of every variety of hue, and, as it were, fused into each other. Professor PAGE states that it resembles more nearly some specimens of ice which he had examined, than anything else. The caoutchouc and gutta-percha must be kept under considerable tension during the examination.

PROXIMATE PRINCIPLES.—PAYEN states that purified gutta-percha is formed of three proximate principles, very different from each other as regards their properties, but isomerical as regards their elementary composition, and also isomerical with purified caoutchouc, being all of them carbides of hydrogen, and each represented by the formula $C_8 H_7$. These three proximate principles, which he terms *gutta*, *albane*, and *fluavile*, he describes as being found in gutta-percha in the following variable proportions:—

	Centesimally.	
Gutta,	78 to	82
Albane,	16 to	14
Fluavile,	6 to	4
	100	100

PAYEN commenced his experiments by submitting the gutta-percha to the action of alcohol. Reduced to thin leaves, it was treated, in a close vessel, with fifteen to twenty volumes of cold anhydrous alcohol; the heat was raised slowly, by means of the water-bath, to the point of ebullition, 172°, and kept at this temperature during several hours; the liquid was then filtered whilst boiling, and left in a closed flask, when it was found, at the end of from twelve to thirty-six hours, to begin to deposit on the sides of the vessel, and on the surface of the solution, white opaline granules, distant from one another, but some of them in groups; their size gradually increasing for some days. These granules, carefully examined under the microscope, were found to have the form of spherules truncated by the sides of the vessel. Their surface was either smooth or bristling with very small, transparent, elongated, lamellated crystals. Some superficial fissures appeared to indicate that these spherules were formed of a sort of transparent yellow nucleus, covered with a white pellicle; and PAYEN ascertained on examination that such was really their singular crystalline structure, of which perhaps no other example is known. He found also that cold anhydrous alcohol dissolved the whole of the yellow internal spheroidal substance, while the superficial pellicles, in the interior of which the alcohol had then substituted itself for the solid yellow globules, appeared consequently whiter and more transparent. The alcoholic solution, which had been for some days depositing this complex spheroidal crystallization, was again capable of taking by heat a further portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallize on cooling, and thus to be developed respectively in the white pellicle and yellow nucleus. The extraction was completed by returning the boiling alcohol several times upon the gutta-percha till nothing more was dissolved.

The solid substance, which entirely resisted the action of the alcohol, possessed, with some modifications, the principal properties of crude gutta-percha; and this is what PAYEN termed *pure gutta*, or simply *gutta*. Of the two other organic principles developed by the method which he adopted, the *white crystalline resin* which covered the spherules was what he called *albane*; and the *yellow resin*, which was much more soluble in cold alcohol than the other, was the substance which he termed *fluavile*. The commercial varieties which he examined gave him the proportions above stated; their special properties were as follow:—

1. *Pure Gutta.*—It will be seen that the most abundant of the three principles distinguished by PAYEN is the so-called *pure gutta*, or that portion insoluble in alcohol, and which is described by the same chemist as being insoluble in ether. M. PAYEN probably failed to effect its solution, from the circumstance that he employed the same gutta which had previously been treated with alcohol; in that case, according to M. ARPPE, it is not dissolved by ether.

PAYEN describes his *pure gutta* as presenting the principal properties of the commercial substance. It is white, transparent at a temperature of 212°, when all its parts are melted together; opaque or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. He states that this structure appears still more distinct than in the natural substance containing all these principles. In thin sheets, and at a temperature of 50° to 86°, it is supple, tough, extensible, but not very elastic. At 112° it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230°. Heated beyond this point, it melts, boils, and distils, furnishing a pyrogenous oil, and eliminates carbides of hydrogen. Its behavior with acids, alcohol, and oils, chloroform and bisulphide of carbon, is the same as the commercial article.

After the extraction, by means of ether, of the two resins contained in the thin leaves of white or purified gutta-percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, inclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82°, an alteration which appeared to depend on their porosity, the action of the air, and perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties; they were brittle; exhaled a very distinct sharp odor; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion obtained by the evaporation of the ether, and exsiccation at 194°, was glutinous and translucent; it became opaque and hard by cooling down to 14°.

The same chemist states as a fact which he had personally ascertained, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discolored, and that their substance had become in great part soluble in ether.

2. *Albane.*—The albane, or crystalline white resin, presents itself as a light pulverulent mass, apparently opaque, which, under the microscope, exhibits thin transparent lamellar crystals. From 32° to 212° it does not experience any sensible change; its fusion commences at 320°; at 347° to 356° it acquires an oleiform fluidity and complete transparency, without any noticeable color; it solidifies on cooling, shrinks, which causes it to split, and remains transparent and a little heavier than water.

The crystalline resin is not attacked or readily moistened by either cold or boiling water; or by hot or cold caustic alkaline solutions, ammonia, and the various dilute acids. Monohydrated sulphuric and nitric acids attack it rapidly, producing similar phenomena to those observed in their action upon pure gutta.

Hydrochloric acid, on the contrary, does not act upon the white resin.

3. *Fluavile or yellow resin.*—This amorphous transparent resin, of a lemon or orange color, according to its thickness, is a little heavier than water, solid, and even hard and brittle at 32°; it gradually becomes more flexible in proportion as the temperature is raised; at 122° it becomes pasty; it does not become completely fluid below 212° to 230°. Heated beyond this point it boils, but then gradually undergoes considerable alteration, becomes brown, and evolves acid fumes and carbides of hydrogen. It strongly retains the alcohol in which it has been dissolved; but is separated from it by heating *in vacuo* to 212°, until bubbling entirely ceases.

This resin is soluble in the cold in alcohol, ether, benzol, turpentine, bisulphide of carbon, and chloroform: all these liquids, when evaporated, leave as residue the amorphous resin. Dilute acids, concentrated alkaline solutions, and ammonia, do not attack the yellow resin. Monohydrated sulphuric and nitric acids act upon it rapidly, producing phenomena analogous to those exhibited with the other two principles. Hydrochloric acid, even in its saturated solution at 68°, is without action upon it. But the most remarkable character of this resin is the power of forming, under the circumstances already indicated, those globose crystals covered with a white pellicle of another resin, and presenting in their complex form the appearance of opaline spherules.

MANUFACTURING PROCESSES.—It has been stated that the gutta-percha, after its extraction from the tree in the form of a milky juice, is first allowed to coagulate, and then made up into lumps or blocks of some pounds' weight. These, as they arrive in Europe, are far from being pure, for besides containing chips of bark, leaves, and other adventitious substances which fall accidentally among the juice, the natives make no scruple of introducing stones, earth, and other rubbish, to increase the weight of the blocks. The first and most essential process in the manufacture of gutta percha is, therefore, its purification; and in fact, ever since its introduction into Europe, gutta-percha has found everything provided for the purpose of cleansing it, being worked by processes and instruments very similar to those which had been previously employed in the purification of india-rubber. It is also vulcanized, and cut or moulded into different shapes, in much the same manner. The general nature of the operations may be briefly described as follows:—The blocks of gutta-percha being first cut into slices by revolving knives, are softened by means of hot water, and then divided and torn into shreds by the same machine that is used for india-rubber, which serves also to knead the gutta-percha in such a manner that the crushed stones and earth may be separated from it on being diluted in the water; it is then dried, and submitted, by means of a powerful machine, to a mastication similar to that which caoutchouc is made to undergo; and when, after some hours of kneading, the mass has become homogeneous and sufficiently softened, it is extended by the drawing-mill into cylindrical cords, moulded into tubes of various diameters, or spread out by means of the flattening machine into sheets of different thicknesses, which are finally divided into bands or slivers, and from these are cut out with a nipping tool the pieces which are required to be employed in different uses.

These various operations, together with the vulcanization of gutta-percha, will now be described successively and in detail—premising that in this country the manufacture is confined to two or three companies, which work the various patents secured from time to time by Mr. HANCOCK and others. A simple description of the manufacture, as conducted by the London Gutta-Percha Company, will, therefore, embrace all that is really important in the different operations.

PURIFICATION.—*The Cutting Machine.*—When a visitor enters the works of the Gutta-Percha Company, he observes in the yard or court the imported blocks of the raw material piled in great heaps. These blocks, when they are required for use, are first taken from the heaps to the cutting or slicing machine, which is a large solid vertical disc of iron, armed on one side with sharp knife-edges, and revolving at the rate of two hundred turns per minute against the extremity of a sloping iron table. The block of gutta-percha being brought to the edge of the table, is rapidly caught by the knives, and literally reduced to shavings, which fall into a receptacle beneath. Fig. 251 is a side elevation of this machine, and Fig. 252 a front elevation of the disc, with part of the frame. The revolving disc, B, is a circular iron plate, of about five feet diameter, into three slots in which are inserted three radial knives, *b*, b^1, b^2, in a similar manner to the iron of an ordinary plane or spoke-shave. Supported by the frame AF is the shaft D, to one end of which the plate B is attached, and to the other the strap-pulleys EE′, by one of which motion

Fig. 251.

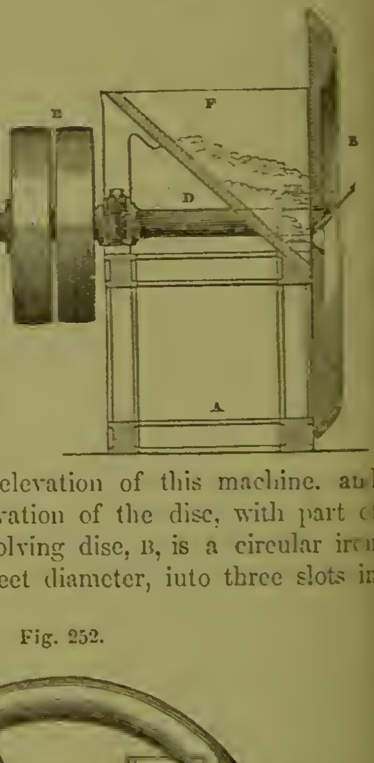
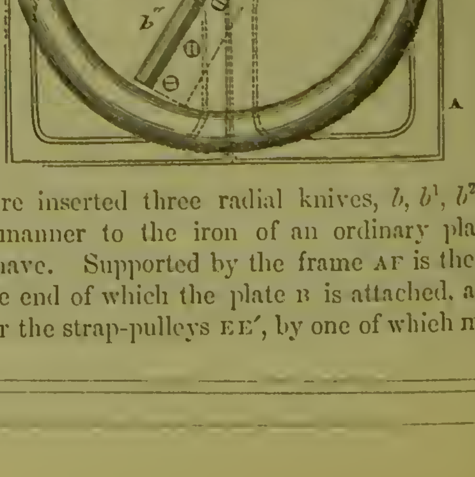


Fig. 252.



is communicated to the shaft from a steam-engine, or any other convenient first mover. C is an inclined shoot, down which the lumps of crude gutta are dropped against the knives of the revolving disc, and are cut into slices of a thickness corresponding to the degree of projection given to the knives.

The knives are represented in Fig. 252 as being straight, but Mr. Hancock, the patentee, states in his specification, that where the gutta-percha to be cut happens to be of a more than usually hard or intractable character, he finds it advantageous to substitute knives of a curved or reaping-hook form, on account of their more gradual mode of action. The machine, which is put in motion at the Gutta-Percha Company's works through the agency of two fifty horse-power engines, is represented as in operation in Fig. 253; and it may be remarked, in passing, that the stones and other adulterative materials which the cupidity of the Malay gatherers has added to the mass, are often discovered by this process, very much to the injury of the cutters.

Fig. 253.

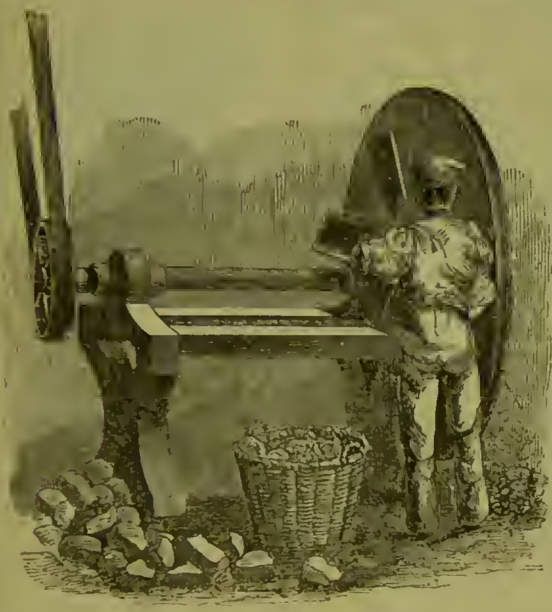
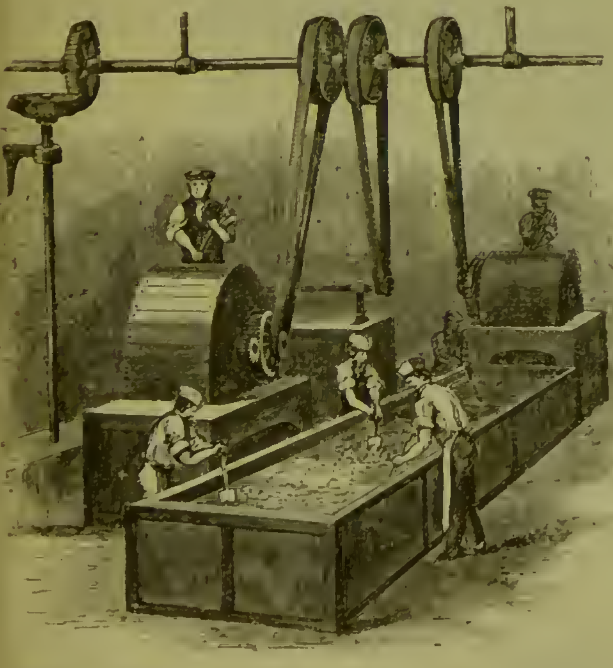


Fig. 254.



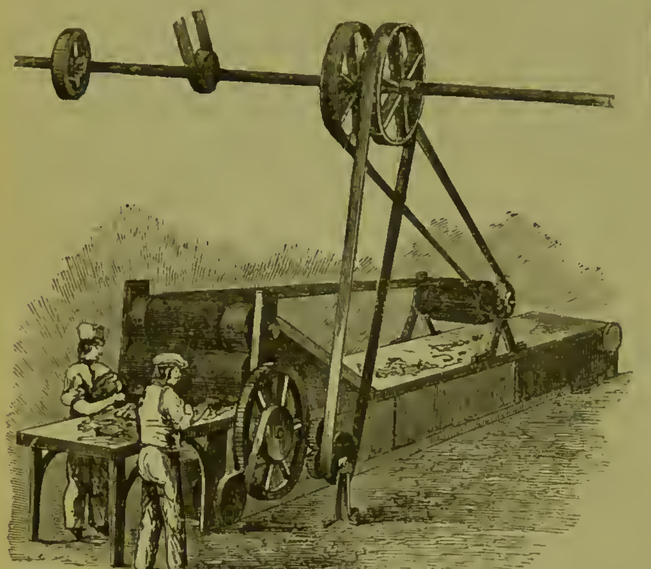
First Boiling and Teasing.—Having been reduced to shavings, the gutta-percha must next be perfectly cleansed of the dirt, leaves, and other extraneous matter. This is effected by throwing the shavings into a large tank containing water, as shown in Fig. 254, to which the waste steam of the engine is conveyed, for the purpose of boiling. This process softens the whole into a fluid mass, and separates the more considerable impurities, which, by the agitation of the boiling, sink to the bottom. The greater part of the rubbish having thus subsided, the partially-purified gum is collected into one mass, and carried to what is called the *teaser*—a sort of large circular box, containing a cylinder or drum covered with rows of bent jagged teeth. Two of these machines are represented in the same figure. Revolving at the rate of about eight hundred turns in a minute, the teaser quickly tears the mass into shreds, which fall into a vat of water beneath. Here the gutta-percha, being in its naturally porous state lighter than water, floats upon the surface, while the impurities disengaged from it by the action of the teaser fall to the bottom. The gutta-percha is now cleansed from all impurities; it has a crisp and fresh-looking appearance, and is ready for the next operation, which consists in working and kneading it into a homogeneous mass.

Second Boiling and Kneading.—The operation of teasing is followed by a second boiling, which has the effect of blending the fragments of the now purified substance into a warm soft mass, and in this state it is introduced into the *kneaders* or *masticators*, which are thick, strong, circular iron boxes, about three feet long and a foot and a half deep, containing revolving cylinders armed with cogs or pins on their surface. The cylinders and their containing boxes are of cast-iron, and are heated by steam. The gutta-percha, when introduced, is thus kept in a soft state, and being carried round by the action of the revolving cylinders, it is forcibly squeezed against the sides of the box; while, by the action of the cogs or pins, every air-bubble is expelled, and the whole is brought to a perfectly homogeneous mass of uniform consistency, without a particle of water in its composition.

In April, 1853, a patent was taken by Mr. Nickels for using two rollers with screws on their surfaces, in place of teeth or projections, for masticating or kneading. The rollers work parallel, and nearly up to each other; and in each of the threads of the screw-rollers there are notches, which the patentee prefers to be made in a diagonal direction. This form of machine is considered the most effective, and is now most commonly used.

Rolling into Sheets.—In the state in which the gutta-percha comes from the kneading or masticating machine, it is ready for being manufactured into different shapes, and, with this view, it is now rolled into sheets, or pressed out into tubes. The first operation is required to prepare it for its subsequent conversion to most of the useful and ornamental purposes to which it is applied; and, with this view, the kneaded mass is carried to the *rolling machine* represented in Fig. 255. This apparatus is similar to that employed in paper-mills, the gutta-percha, like the soft paper, passing on an endless band between steel cylinders placed at the requisite distances apart, according to the thickness of the sheet required. By means of screws the cylinders can readily be adjusted to produce with equal ease the stoutest driving band, or the thinnest *gutta-percha tissue*, so successfully employed as a substitute for oiled silk, hydropathic bandages, *et cetera.* After passing between the rollers in a soft and impressible state, the sheet performs a long journey on the endless band, in the course of which it gradually cools and hardens, and finally appears at the other end a smooth, firm, flat sheet, which admits of being received and wound on a drum till the requisite length has been worked off. If, however, the sheet be too thick to cool sufficiently by merely travelling the prescribed distance, it is ventilated, as it passes along, by a series of fans like those of a winnowing machine.

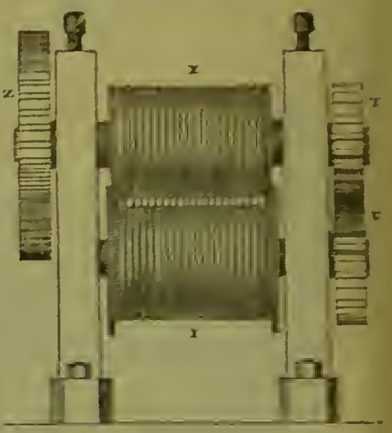
Fig. 255.



DRAWING RIBANDS AND CORD.—When the material is required to be in bands or strips, it is generally cut into that form, while being rolled into sheets, by a series of knives so placed as to divide the sheet while yet plastic into any number of bands of the required width, just before quitting the rolling machine. The knives are set upright in a frame, edge foremost, at the requisite distances from each other, and, without interrupting the progress of the sheet, they slice it into bands, which, as before, are made to travel till they cool, and are then wound upon a drum.

In 1847, an ingenious machine was patented by Mr. CHARLES HANCOCK for cutting gutta-percha into narrow ribands, and manufacturing it into thread or cord of any required shape. A front elevation of as much of this machine as is necessary to understand its construction, is given in Fig. 256, in which X Y are two grooved rollers, made of steel or iron, and mounted in suitable framework. The grooves of each roller are semicircular, so that when the grooves of one roller are brought opposite to those of the other, they form together a series of circular holes, as shown in the figure, at the line of contact between the two rollers. The under roller is flanged at both ends, and the two ends of the upper roller are made to fit inside of the flanges, in order to keep the cutting edges from slitting or being damaged. From the prime mover, motion is communicated to the toothed wheel, Z, on the shaft of the roller X, and thence through the wheels T and U, to the roller Y. To cut thin sheets of gutta-percha with this machine into narrow strips or ribands, the material is passed through it cold, and only the cutting edges are brought into operation. To make round thread or cord by means of it, a sheet of gutta-percha, of a thickness equal to the diameter of the holes formed by the grooves of the rollers, is passed through it at a temperature of about 200°, by supplying the material from a feeding chamber, heated to that degree by steam or otherwise; and the threads or cords, after passing between the rollers, are received in a tank of cold water, from which they are wound on reels or drums, conveniently placed for the purpose. Or, by another method, the gutta-percha is employed in a plastic state, and passed towards the machine under a gauge, after the manner employed in the caoutchouc manufacture.

Fig. 256.



Should it be desired to produce cord of a semicircular section, the lower grooved roller is replaced by a plain roller; or should cord of a form neither circular nor semicircular, but square, triangular, hexagonal, or of any other angular form be required, two cylinders are employed, grooved in such a manner as to produce the desired shape.

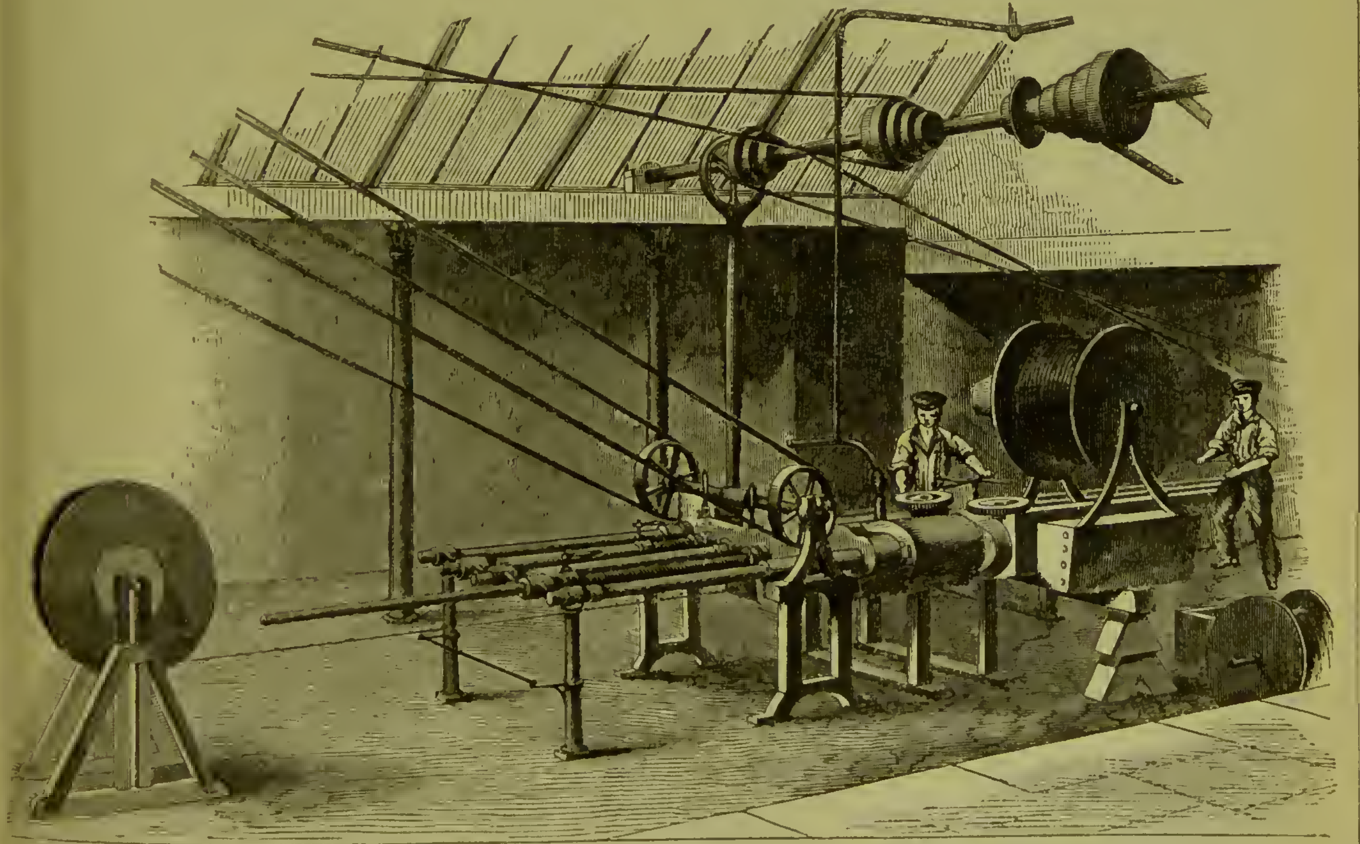
Cord and thread are likewise manufactured by means of a stamp, bearing a number of close parallel sharp edges, which are brought down upon a sheet of gutta-percha so as to cut it nearly through in a series of corresponding parallel lines. The narrow slips are then severally torn off, and polished up by hand for use.

CUTTING, SHAPING, AND MOULDING.—Besides the operations above-mentioned, the gutta-percha, when formed into sheets, admits of an infinite variety of applications. Softened by boiling water or steam, it may be shaped into any required form by the hand, the knife, the mould, and the press. The numerous workshops in the establishment of the Gutta-Percha Company are crowded with men and boys engaged in various operations. One apartment is occupied as the cutting and stamping room, and here the paper-cutting machine, invented by Mr. WILSON, is brought into extensive use, while moulds of every description are being employed to produce the different articles. If shoe-soles are required, the cutting machine is brought down upon a pile of stout broad bands, dividing a dozen of them at one operation into rectangular pieces, which are afterwards cut *en masse* into the required shape by means of a sharp-edged frame. In one place are seen revolving tables, bearing inverted iron moulds, from which workmen are turning out buckets, bowls, bottles, and mariners' hats, while others are moulding bosses for flax-mills, rings, whips, *et cetera.* In one apartment cisterns and trunks for emigrants are being lined; in another, ornamental mouldings, medallions, pen-trays, ink-stands, picture-frames, and other fancy articles, are stamped from electrotype copper dies or wooden moulds. For the stamping or moulding, the sheets are cut into pieces, and each piece is warmed sufficiently to take the impress of the die.

Gutta-Percha Tubing.—Perhaps the most important use to which gutta-percha has been applied is that of tubing, in which form it is extensively used for pump-barrels, ship-pumps, feed-pipes for locomotive engines, siphons for mines, suction or ejection pipes for fire, garden, and washing engines; and, being unaffected by acids, it is also available in this form for bleaching with chlorine and other chemical purposes. Accordingly, while the process of sheet-rolling, already described, forms the basis of a large department of the manufacture, the making of tubes constitutes another important and distinct department—the tubes being formed directly from a softened mass of the purified material, which has passed through the kneading or masticating machine. The process, while highly ingenious, is exceedingly simple. The softened material is forced by a piston through a steel cylinder, terminating in a mould that consists of a solid circular piece of metal set within an iron tube, the space between the two being the thickness required. The gutta-percha thus leaves the mould in a tubular shape, but would immediately collapse unless subjected, until it cools, to an even pressure both within and without. To accomplish this, it is received from the mould into a canal of water about fifty feet in length, along which it travels, being wound off upon a drum at the other end. The water, filling the interior, and pressing equally upon the outside of the tube, preserves it in perfect shape while it speedily cools it into hardness. The feeding cylinder is so contrived as to admit of being constantly replenished with new material, so that a tube of one thousand feet has been manufactured without a single break, being the longest ever made in one piece of any substance whatever.

Coating Telegraph Wires.—Another application of gutta-percha, which may vie in importance with that of tubing, though not of such varied usefulness, is that of covering wires for telegraphic purposes. In this respect its high insulating power, combined with its flexibility and imperviousness to water, render it of essential service; and, indeed, it may be doubted whether the submarine lines of telegraph, uniting different nations, islands, and continents, could have existed at this day without the valuable assistance rendered by gutta-percha. Its introduction into Europe, contemporaneously with the inauguration of these magnificent projects, by which the earth is being girdled with wires of living intelligence, can scarcely be regarded otherwise than as an express dispensation of an overruling Providence to advance the progress of civilization and human happiness. A good piece of gutta-percha, says Dr. Faraday, will insulate as well as an equal piece of shell-lac, whether it be in the form of a sheet, a rod, or filament; but being tough and

Fig. 257.



flexible when cold, as well as soft when hot, it will serve better than shell-lac in many cases where the brittleness of the latter is an inconvenience.

A thin coating of gutta-percha may be communicated to a wire by drawing it through a glass or metal tube, filled with gutta-percha in solution, or rendered fluid by heat; but for the conducting wires of the electric telegraph, whether intended to be buried in the earth, or to form the core of a submarine telegraph cable, the coating, to insure perfect insulation, must possess considerable thickness, varying from one-sixteenth to upwards of one-eighth of an inch.

Accordingly, telegraph wires are now coated in much the same manner, and by mechanism much the same in principle, as that employed for moulding tubes. This will be seen from the preceding woodcut, Fig. 257, which exhibits in actual operation the machinery employed by the Gutta-Percha Company for coating the wires of the great Atlantic cable. The central conducting wire of this cable is *a strand* made up of seven wires of the purest copper of the gauge known in the trade as No. 22; it is about the sixteenth of an inch in diameter, and is formed of one straightly-drawn wire, with six others twisted round it. This strand received a coating of three separate layers of refined gutta-percha, which together bring its diameter up to about three-eighths of an inch. The gutta-percha employed for this great work was prepared with the utmost possible care. Lumps of the crude substance were first rasped down by a revolving toothed cylinder, placed within a strong hollow case. The raspings were then passed between rollers, macerated in hot water, and well agitated. They were next washed in cold water, and then, by means of a hydraulic apparatus, driven at a boiling water temperature through wire-gauze sieves, attached to the bottom of hollow vertical cylinders. Emerging from the sieves in plastic masses of exceeding purity, the gutta-percha was then submitted to the powerful action of the masticators already described, to expel from the purified substance the last traces of water, and to render it sound, compact, and homogeneous throughout. When thoroughly masticated and kneaded, it was then introduced into the horizontal cylinders, shown in the drawing; and through these, which were heated by steam to keep the gutta-percha in a uniformly soft and plastic state, it was squeezed by means of screw pistons, worked down slowly but resistlessly by the machinery. Under this pressure the gutta-percha emerged, as in tube-moulding, through a die, which received the termination of two cylinders, and which at the same time had the strand of copper wire moving along through its centre, instead of being stationary like the mandril in tube-moulding. The strands were drawn forward between the cylinders and through the die by a revolving drum. They entered the die in the form of bright copper wire, and issued from it like brown tubes or cords of gutta-percha. Six of these strands are represented in the drawing as being coated together, ranging along side by side; and this operation was repeated a second and third time, to produce what is termed *the core* of the Atlantic cable.

PATENT MOULDING.—In March, 1855, a patent was taken by Mr. CHARLES GOODYEAR for ingeniously extending the principle of the apparatus above-described to moulding of every description; in other words, the machine which he employs is constructed in a similar manner to those now employed for coating telegraph wires, and for moulding tubes. Like these, it consists of a cylinder or barrel, into which the gutta-percha is introduced, and into the cylinder or barrel a piston works being operated on by a screw or rack-and-pinion, or otherwise. In this case, also, the cylinder is enveloped in a steam-jacket to keep the contained material at a suitable temperature, and in the end of the cylinder is formed a nozzle or orifice, through which the contents are *forced into the mould* by the motion of the piston. The moulds are constructed of two or more pieces of metal, which are held together with bolts and nuts; they are formed with a suitable interior configuration for producing the article desired; and there are two or more passages which lead into the cavity, the largest of which is for the purpose of allowing the plastic substance to pass into the mould, and the others for allowing the air contained in the mould to escape. When the piston advances, it forces the gutta-percha from the barrel or cylinder into the mould, until it begins to escape from the air orifices. The piston is then arrested, and the mould, when removed and emptied, is ready to be again filled.

VULCANIZED GUTTA-PERCHA.—Among other properties in which gutta-percha strikingly resembles caoutchouc, is the change which it undergoes when intimately mixed with sulphur or its compounds, and afterwards submitted to a somewhat elevated temperature in close vessels. By this *vulcanizing* treatment, as the process is termed, it is rendered, like caoutchouc, less readily affected by changes of temperature, and more permanently soft and elastic, so as to be better fitted for bands and other purposes. To effect this remarkable modification, it is subjected to precisely the same methods of treatment as caoutchouc, and, indeed, it is frequently combined with that substance to give it the pliancy and elasticity required for some of its applications. Accordingly, most of the patents which have been taken in connection with this subject, are not confined to gutta-percha, but embrace also caoutchouc and various combinations of these with each other, as well as with other substances.

In Vol. I., pages 448 and 449, of this work, there are two methods described of vulcanizing caoutchouc—one of which consists in kneading it with sulphur or its compounds; the other, in immersing it in liquid compounds which hold sulphur in combination, and afterwards, in both cases, exposing it to the requisite heat. Gutta-percha may likewise be vulcanized by either of these methods, or by exposing it to the action of a mixture of steam and sulphurous vapors in HANCOCK's apparatus, which was patented in 1847, and is figured and described at the pages above referred to.

In March, 1846, Mr. ALEXANDER PARKES of Birmingham obtained a patent for vulcanizing caoutchouc and gutta-percha, by dissolving it in bisulphide of carbon, coal-naphtha, turpentine, or any other suitable solvent; preferring, however, the bisulphide of carbon for the purpose, along with chloride of sulphur. The caoutchouc or gutta-percha, when taken out of the solution, is suspended in a drying-room or stove, heated to about 80°; and, when the solvent has evaporated, the gutta-percha is well washed in water, or boiled for one hour in a solution of caustic potassa or soda, containing one pound of the alkali to a gallon of water. The gutta-percha being then dried, is ready for use.

Mr. Hancock, in the specification of his first patent, of November, 1846, recommended the sulphurizing of gutta-percha by means of sulphides, such as orpiment or liver of sulphur, in preference to sulphur itself; and in that specification he stated, that though a portion of sulphur might be used in place of an equal portion of sulphide, yet he considered the use of sulphur to be altogether objectionable, because of its offensive smell and tendency to efflorescence. Subsequently, however, he ascertained, as stated in the specification of his second patent, of date February, 1847, that if a very minute portion of sulphur be used along with a sulphide, a better result is obtained from a combination of the two than from either substance alone. The proportions which he found best in practice were six parts of sulphide of antimony, sulphide of calcium, or some other analogous sulphide, and one part of sulphur, to every forty-eight parts of gutta-percha. When the mixture of these materials has been effected, he places the compound in a boiler, and raises it, under pressure, to a temperature of 260° to 300°, in which state he leaves it for a period varying from half an hour to two hours, according to the thickness of the materials; by which time it becomes completely vulcanized, or, in other words, *metallo-thionized*.

In August, 1851, a patent was taken by Mr. Stephen Moulton, for applying to gutta-percha his process for vulcanizing caoutchouc with hyposulphite of lead, to which allusion has been made in the article Caoutchouc, Vol. I., p. 450. The same process is applied to a combination of equal parts of gutta-percha and caoutchouc, as to either of these alone; and when it is desired to produce a hard-cured gutta-percha, or a hard composition of gutta-percha and caoutchouc, described by the patentee as similar to horn or ivory, he adds from two to twelve ounces of calcined magnesia to each pound of gutta-percha composition, alone or combined with caoutchouc. The whole is then exposed in a close vessel to steam or dry heat of from 250° to 300°, for a period of time which will vary from two to ten hours, according to the thickness of the material and the quantity of goods introduced in one mass. The patentee adds, that after the gutta-percha goods, whether in the form of coated cloth, sheet gum, moulded, or any other article, have undergone this process, which he terms *curing*, they will be found not only impermeable to wet, but extremely tenacious, possessing the elastic property of the cured caoutchouc, and also unaffected by changes of temperature.

In December, 1856, a patent was taken by Mr. Emory Rider of London, for improvements in the method of vulcanizing gutta-percha; the principal novelty of which consists in the addition of one part of sulphur, or an equivalent thereof in some of its compounds, and *one part of litharge*, to sixty-six parts of the gutta-percha, prior to the exposure of the latter to a temperature of 235° to 245°, for the purpose of expelling the volatilizable ingredients. The sulphur or hyposulphite of lead or zinc, or the artificial sulphide of lead, or other compound of sulphur employed for this purpose, is first mixed with the gutta-percha, and then thoroughly incorporated by passing the mixture repeatedly between metallic rollers heated to a temperature sufficient to make the gutta-percha very soft, and easily kneaded or worked. The mode of effecting this, which Mr. Rider states that he has found to be most beneficial in practice, is by the employment of a machine in which the rollers work at different degrees of speed, and produce a teasing or grinding action, which he regards as of considerable importance in working the material. After being thoroughly incorporated and ground, the material is placed in a strong metal vessel, which is filled to about one-third of its capacity, so as to leave ample room for the swelling or expansion of the compound under the action of heat. It is then exposed to a temperature of about 235° to 245° for about three hours, and for this purpose the patentee prefers steam-heat, by which he is enabled to subject the gum under treatment to a greater pressure, and to obtain a more regular degree of heat than by other means. He adds, that the gutta-percha, having undergone this preliminary heating, may be vulcanized by the application of a much lower degree of heat than has been ordinarily used in that process, and that he has found a temperature of 255° to 265° to be sufficient to effect the change.

Renovation of Vulcanized Gutta-Percha.—The fact that caoutchouc or gutta-percha, or compounds of these substances which have undergone the change produced by the vulcanizing process, can in that state be only very partially acted on by solvents, and with difficulty wrought by any of the usual means employed when operating upon the natural substance, renders it necessary to mould and finish the articles before they are submitted to this process, or to vulcanize them in the moulds, having previously mixed the gutta-percha with the sulphur in the kneading or masticating machine. By the process of vulcanizing, properly so called, is meant the subsequent heating, which can be applied in the act of moulding, when the articles require to be submitted to that operation.

But that very circumstance which renders it impossible to shape or manufacture gutta-percha into new forms after it has passed through the vulcanizing process—namely, the difficulty of acting on the vulcanized material either by means of heat or the usual solvents—must entail a considerable loss in the shape of waste, unless it be possible by some expedient to renovate the vulcanized gum, and restore it to its original state. It was stated in the article Caoutchouc, Vol. I., p. 448, that the separation of the sulphur from that substance presented so many difficulties that it had not yet been accomplished. It may here be remarked, however, that several attempts have been made to effect this desirable object, and that, so early as in 1846, Mr. Parkes proposed and patented a method which is attended with partial success. According to this method, eight or ten pounds of the waste-cuttings, or old and worn articles, either of caoutchouc or gutta-percha, are boiled in twenty pounds of the chloride of calcium, for a longer or shorter period according to the thickness or bulk of the substance, until, by testing a few of the pieces, it is found to be in a state to be readily united by pressure. It is then removed from the bleaching liquor, and washed, first in a hot alkaline water, and afterwards in pure water, also hot, when he states that the substance may be re-manufactured, and again submitted to either of the vulcanizing processes already described.

In January, 1856, a patent was granted to Mr. NATHANIEL SHATTSWELL DODGE, for a method which is stated to be more effective, and by which, in the words of the patentee, scraps or waste pieces of vulcanized india-rubber, or vulcanized gutta-percha—such, for example, as old shoes, railway-buffers, carriage-springs, *et cetera*—may be rendered fit to be re-used or worked up into useful articles or fabrics, *without requiring to be re-vulcanized.* For this purpose, the material to be treated, if existing in large pieces, is reduced into smaller ones, and is then placed in a vessel capable of being hermetically closed or made air-tight. To this material is now added pure alcohol—*alcohol absolutus*—and bisulphide of carbon, in the proportion of a quarter of a pound of the former and ten pounds of the latter to one hundred pounds of the material, the alcohol and the bisulphide being previously mixed together, and then poured over the material to be treated. The vessel containing the ingredients is then closed air-tight, and allowed to remain so for about two hours, more or less, at the expiration of which time the cover may be removed, when the whole, says the patentee, is found to be in a soft, plastic, or gummy state, and ready to be ground in the ordinary way of grinding such gums, for the purpose of manufacturing it into various useful or ornamental articles without repeating the process of vulcanizing. By adding a larger proportion of the alcohol and bisulphide of carbon, the gums may be reduced to a liquid state. The relative proportions of the two may, however, be varied according to circumstances, and the effect which it is desired to produce.

VARIOUS COMPOUNDS OF GUTTA-PERCHA.—In addition to that combination of gutta-percha with sulphur or its compounds, which, with the subsequent exposure of the material to a high temperature, constitutes the process of vulcanizing, a great variety of patents have been taken for combining this substance with other materials to render it softer or harder, more or less elastic, or more durable, and so to fit it for one or other of the almost innumerable purposes to which it has been proposed to apply it. To enumerate the whole of these patents in detail, so as to describe with precision the various processes and applications proposed, would both exhaust the patience of the reader and exceed the limits of this work. It is necessary, however, to give an abstract of the most important of these patented compounds and processes, to prepare the reader for a subsequent enumeration of the wonderful variety of uses to which this valuable substance has already been rendered subservient; and, in doing so, the Editor conceives that the best arrangement he can adopt is to follow the order of dates:—

Mr. HANCOCK'S patent for January, 1846—the first patent taken on the subject—embraced a claim for making a compound elastic water-repelling substance, for manufacturing purposes, by mixing gutta-percha with jintawan, a somewhat similar material then recently imported from the East Indies, and also with caoutchouc, or with both, in proportions varying according to the softness, stiffness, pliancy, or extensibility which it was proposed to give to the compound. He states in his specification, that a good composition for bands or tape is formed by combining fifty parts of gutta-percha, twenty-four parts of jintawan, twenty of caoutchouc, and six of orpiment. These are incorporated together in the masticating machine, and the combination is facilitated by moistening the mass with rectified oil of turpentine, or some other solvent. The orpimented or sulphurised compound is then exposed to a heat of from 300° to 340°, for a period varying according as the temperature is higher or lower. With a heat of 300° about sixty minutes are required; while fifteen minutes are sufficient for a temperature of 340°. The required heat may be obtained either by means of high-pressure steam, or of water heated under pressure, or of hot air.

Another claim embraced in Mr. HANCOCK'S first patent consisted in a method of improving gutta-percha in softness and pliancy, as also its combinations with caoutchouc and jintawan, supposing the substance, whether single or compound, to have been previously sulphurised. For this purpose, he subjects the article, whether in the state of blocks, sheets, threads, or any other form, to the action of sulphurous acid, either by exposing it to the acid in the state of vapor, or by steeping it in water impregnated with the acid, or by spreading over the article a paste made of sulphuric acid and ivory, or bone-dust, or animal charcoal, and then placing it in a steam-heated vessel or chamber.

Another method of producing the same effect—claimed also in the same patent—consists in adding to the gutta-percha and its compounds when passing through the masticating machine, and whether they are mixed or not with orpiment or any other sulphide, about ten per cent. of vegetal wax or tallow.

In October, 1847, a patent was taken by Mr. THOMAS FORSTER, for combining gutta-percha with animal charcoal, hydrate or milk of sulphur, ground whalebone, fragrant essential oils, musk, tonquin beans, orris root, or gum-benzoin, and for applying all or either of these ingredients, alone or in combination with caoutchouc or other matters, to fabrics or leather for clothing, lining for railway carriages, cart and rick covers, wrappers for goods, *et cetera*. For this purpose the gutta-percha is first cleansed or purified, and then put into a hot mastrating pan with one or more of the substances above-mentioned, in the proportion of four parts of the gutta-percha to one of animal charcoal; or four of gutta-percha, two of india-rubber, and two of animal charcoal. The latter should be of the finest description, and carefully sifted through a very fine sieve. When these matters are thoroughly incorporated, a portion of any solvent is to be added—by preference, oil of coal—in such proportions as are needful for the particular fabric to be coated. The patentee found equal weights of each to be good proportions. When the gutta-percha and solvents are well combined by heating them in a vessel enveloped in a steam-jacket, and are in a fit state to be spread upon the fabrics, Mr. FORSTER adds orris root or other perfumes in such proportions as are necessary to give the goods the desired scent; but if caoutchouc is a component part of the compound, he says it is best to use orris root, tonquin beans, musk, or gum-benzoin only, as the fragrant essential oils are apt to act injuriously upon the rubber in the course of time. For coarse goods, such as carriage covers and the like, he takes gutta-percha four parts, ground whalebone and hydrate of sulphur, each one part, and one-sixteenth part of any mineral preservative of vegetal matter—by preference, arsenic—works the whole in a mastrating pan, and afterwards spreads it upon the fabrics, with or without a solvent. If the fabrics are required to be of any particular tint, he adds to any of the above compositions the color necessary to produce it.

In forming such articles as are required to resist moisture, as buttons, tea-trays, military ornaments, *et cetera*, he first saturates the fabrics with any water-repellent matter, preferring for this purpose boiled linseed oil, dries them thoroughly in a stove, and then coats them with the first-mentioned composition of gutta-percha. In making panels for carriages, doors, boxes, *et cetera*, he uses staves of wood, deal as the cheapest, and coats them with any of his gutta-percha compositions, using one part of the composition to two of the solvent. When the solvent has thoroughly dried, he takes pieces of the required size and heats them, lays one upon the other, taking care to reverse the grain of the wood, and then presses the whole while hot, keeping the pressure upon them till cold.

The compositions he prefers for moulding without fabrics are—gutta-percha four parts, bone-charcoal two parts, and one-sixteenth part of arsenious acid; or, gutta-percha four parts, ground whalebone or the rasping of horns and hoofs two parts. If a hard composition of a light color is required, he uses gutta-percha three parts, ivory or bone-dust one part, and Cornish clay a half part. He states that a large quantity of animal charcoal or bone-dust will make these compositions much harder at the expense of their toughness. The articles he makes directly from these solid compositions are carriage and other wheels, ornamental leaves and scrolls for furniture, military and other ornaments for harness, trays, frames, cornices, leaves, and flowers. The quantity of perfumes to be used in any of these compositions must depend upon the purity of the material. He finds, however, that of orris root half a pound to every five pounds of the composition is necessary; of benzoin, two ounces to every five pounds; of the essential oils, about half an ounce to five pounds.

To finish the surfaces of fabrics or leather prepared with gutta-percha or its combinations, he coats them with transparent colors, made by combining the colors with oils or varnishes. His mode of operating is as follows:—Suppose the fabric is coated with gutta-percha, and animal charcoal or lamp-black, the color would be a dull black; to improve upon this, he takes ten pounds of linseed oil and twenty ounces of Prussian blue, grinds and mixes, boils the whole gently until it is as thick as treacle, which is readily seen by trying a drop on a bit of glass, and when cold it will be found to be a brown transparent varnish. Apply a thin coat to the surface of the cloth, it will be dry in a few hours, and in drying will absorb oxygen and become blue, thus giving the cloth the fine color of black enamelled leather.

If other colors are required—as red, for example—the fabric should be coated with gutta-percha and vermilion. Take one pound of any oil-varnish, or pale linseed, nut, or poppy oil, previously made *drying* by any of the ordinary methods, and three ounces of crimson lake; grind them well together, and coat the fabric with a thin layer. If the fabric has been embossed or corked to imitate morocco leather, the result will not be a bad imitation of that article. Of course, any tinge may be produced by a similar process.

In July, 1848, Mr. ANTHONY LORIMER obtained a patent for improvements in the means of purifying gutta-percha, and for new combinations of that substance with other materials. The first part of the method claimed consists in a somewhat intricate system of knives and other machinery for slicing and kneading the gutta-percha; the second consists in combining it with burned clay, burned flint, broken articles of porcelain and earthenware, marble, Portland, Cornish, and other stones, all crushed and sifted; also, the oxides of zinc and copper, the hydrate and oxalate of lime; also a compound of lime slacked with oxalic acid dissolved in water. He uses about three pounds of acid to a bushel of lime, the acid being first dissolved in a quantity of water suitable for slacking that proportion of lime. For making soles for boots and shoes, the great object is to incorporate as much of either of the above matters, or mixtures thereof, as the gutta-percha will take up, and retain a flexible and adhesive character; but in cases where the compounds are to be subjected to strain, such as straps and bands, then smaller quantities of these substances must be combined with the gutta-percha. The gutta-percha compounds so produced may be moulded into any desired form, or pressed into sheets between rollers.

In November, 1854, a patent was taken by HENRI JULES DUVIVIER and HENRI CHAUDET of Paris, for a method of treating gutta-percha with the chloride, bromide, iodide, or fluoride of sulphur, or with the corresponding compounds of phosphorus, boron, silicon, and arsenic, or the bichlorides of tin and antimony; but of these substances the patentees prefer to employ the chloride of sulphur, although they allege that results similar to those obtained by the use of that compound may be obtained by the use of any of the other compounds above-mentioned. The process which they adopt for applying these substances is merely a modification of that vulcanizing process originally patented by Mr. PARKES. The gutta-percha is dissolved in bisulphide of carbon, the solution being made in a close vessel, and at a temperature of 86°. This menstruum, when purified by deposition, is evaporated to dryness, and another clear solution is made, to which from two to fifteen per cent. or more of chloride of sulphur, diluted with bisulphide of carbon, is added and well mixed; or if any of the other substances before mentioned are employed in place of chloride of sulphur, then from fifteen to fifty per cent. should be employed. The patentees make the following interesting statements with reference to the properties of the resulting compounds, according to the proportions in which the ingredients are mixed:—

1. By mixing only two per cent. of chloride of sulphur, or only fifteen per cent. of the other substances, with the sirupy solution of gutta-percha, a compound is obtained which does not materially differ from gutta-percha in its properties.

2. When more than two per cent. of chloride of sulphur is employed, the compound can be extended when heated to 100° or 120°, and it remains extended when cooled, but retakes its original form when again heated; and at about 212° it agglutinates.

3. When five per cent. of chloride of sulphur is added, the compound only differs from that just described in being less softened by heat, and in being slightly elastic when cold.

4. When ten per cent. of chloride of sulphur is added, the properties of the gutta-percha are quite changed, and the compound is unaltered by a temperature of 212°.

5. When above fifteen per cent. of chloride of sulphur is added, the compound becomes horny and harder as the quantity of chloride of sulphur increases.

Articles may be formed from these compounds by pouring them as soon as mixed into metal or other suitable moulds, and there allowing them to set. In the same way the patentees cast blocks of elastic gutta-percha, which are afterwards cut up into pieces of a suitable size for rubbing out pencil marks. The compounds may also be used for glueing or attaching one substance to another, in which case they should be applied in a fluid state, and the two surfaces to be attached should be held together until the cement is quite hard. When attaching leather by this cement, the surface of the leather should be made rough. Or the process may be varied by first coating the surfaces to be attached with untransformed gutta-percha, and then wetting the surfaces with a solution of two to ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon, and pressing the surfaces together till hard.

In a similar manner, articles may be coated with transformed gutta-percha, by dipping them first into a sirupy solution of gutta-percha in bisulphide of carbon, and afterwards plunging them into a bath consisting of two to ten parts of chloride of sulphur dissolved in one hundred parts of bichloride of carbon.

When it is desired that the gutta-percha should penetrate, in place of remaining as a coating on the surface of the article, as is sometimes desirable when treating sheets of fabric, wood, leather, and similar materials; then, in place of simply dipping the article in the solution of gutta-percha, it is allowed to soak therein for twenty-four to thirty-six hours, and is moderately heated, passed between rollers, and afterwards dipped into a solution of ten parts of chloride of sulphur in one hundred parts of bisulphide of carbon.

If the articles subjected to these processes are of such a nature that they would be damaged by the acid vapors formed during the operation, the patentees state that carbonate of soda should be mixed with the solution of gutta-percha, in quantity sufficient to neutralize the acid formed.

In June, 1855, a patent was taken by P. AUGUSTIN GODEFROY for mixing cocoa-nut shells in a finely-ground or comminuted state with gutta-percha in the process of its manufacture, by which it is alleged that the following advantages are obtained:—1. Considerable economy in the manufacture; 2. Greater durability in the product, especially when applied to the manufacture of boot-soles, clogs, goloshes, and other articles exposed to much wear; and 3. Greater elasticity, with the power of resisting a higher temperature than ordinary gutta-percha. By grinding machinery fitted for the purpose, the patentee reduces the cocoa-nut shells to powder of three degrees of fineness. The first, or finest quality, he employs for mixing with gutta-percha intended for tubing, for an insulating coating to telegraph wires, and such like purposes; the second or coarser, for driving-bands, boot-soles, ornamental mouldings, *et cetera;* the third, or coarsest quality, for lining ships, for hut linings, for covering floors and walls, and other similar purposes. The Editor can see no objection to a little adulteration of the gutta-percha for the latter two modes of its application; perhaps the admixture of cocoa-nut shell might even, in some respects, increase its adaptation for these and other purposes; but he doubts how far the same admixture would improve the quality of gutta-percha as an insulator of electricity, or as an admixture in the composition of tubes intended to resist acids, and to be impermeable to moisture.

A communicated patent, dated November 27, 1855, was taken for improvements in the manufacture of india-rubber and gutta-percha, by mixing with these materials calcined shells, or other cheap substances of a like nature, so that when afterwards vulcanized and rendered hard by being subjected to a high degree of heat, the material may be applicable to the manufacture of bobbins, cylinders, rollers, racks, ratchet-wheels, and other parts of spinning machines. Though gutta-percha is embraced in the patent, india-rubber seems to be the substance to which the admixture of calcined shells is considered most applicable.

In August, 1856, a patent was taken by Mr. CHARLES GOODYEAR for an improvement in combining gutta-percha with asphalte or pitch. The method previously in use was, to combine gutta-percha and asphalte by masticating the two together, in the same manner as gutta-percha and india-rubber are combined in the kneading machine. Mr. GOODYEAR's improvement consists in effecting the combination by the aid of hot water, by which the two matters are softened, and made comparatively fluid. For this purpose a close vessel is used, into which the substances are introduced, mixed with a quantity of water, and the temperature is raised to such a degree as to melt both; after which they are to be well stirred, to blend them together. He considers that this melting of them together effects the most perfect combination. And having been thus thoroughly blended in a fluid state, they may, when desired, be further combined with sulphur, also with india-rubber and other matters; and the various compounds thus produced are, when required, subjected to high temperatures, in order to produce the change which is known as *vulcanizing*.

WATERPROOFING AND DEODORIZING.—Mr. HANCOCK'S patent of January, 1846, embraced a method of producing varnishes which might be applied to the waterproofing of leather or cloths; and by applying them either alone or mixed with coloring matters to gutta-percha or its compounds, or to articles made from them, they might have a fine glossy exterior given to them, and the smell of any ingredients which might have been mixed up with them, such as that of the sulphur in vulcanizing, would be effectually removed. For this purpose he mixed gutta-percha and caoutchouc, or gutta-percha and jintawan—using the substances indifferently, so far as regards the proportion one bears to the other—with sulphur or orpiment, or other sulphide, in the proportions that are usually employed for vulcanizing, with about eight to ten parts of animal or vegetal wax, or animal or vegetal fatty matter, and then dissolved in rectified spirits of turpentine, and evaporated. He adds that these varnishes, mixed with colors, may be used for the purpose of painting or printing cloth, leather, or any other fabric, and will be found very useful as waterproof cements, particularly in combining gutta-percha and its compounds with silk, cotton, and other textile fabrics.

In November, 1853, a patent was taken by Mr. JOSEPH FRY for improvements in preparing solvents for india-rubber and gutta-percha, and in rendering waterproof fabrics free from smell. With reference to the first claim, it is stated in the specification, that previously the solvents employed for india-rubber and gutta-percha had been distilled and rectified before their application; but it had been found by the patentee that these solvents are improved if india-rubber or gutta-percha be combined with the solvents before distilling them, or be present in a certain proportion during that operation. The solvents usually employed for waterproofing purposes are turpentine and coal-naphtha, or coal-oil. In proceeding to distil one or other of these, he introduced into the still, along with the solvent, from four to six ounces of the india-rubber or gutta-percha to each gallon of the liquid; and he affirms that the product distilled over is materially improved for the purpose of its subsequent use in dissolving larger quantities of the same substances, while the residue in the still will be found useful for fabricating common or inferior articles, and for waterproofing coarser and lower-class cloths. Or, by another method, the crude solvent might be first distilled without india-rubber or gutta-percha being present, and afterwards be combined with india-rubber or gutta-percha, and again distilled or rectified. The latter mode of treatment is regarded by the patentee as producing the best result.

The second part of the claim, which has for its object the removal of the odor of articles fabricated of india-rubber or gutta-percha in which solvents have been used, consists in subjecting the waterproof cloths, whether before or after being made up into garments or other articles, to the action of steam in a close chamber or steam-chest; and for this purpose the patentee does not find it necessary to employ steam of a much higher pressure than that of the atmosphere. A longer or shorter time is required to remove the odor of the solvent, according to the amount of it that has been present.

DECOLORING GUTTA-PERCHA.—In February, 1853, a patent was taken by Dr. NORMANDY for decoloring gutta-percha by means of animal charcoal, embracing also a novel method of forming it into sheets and balloons. The gutta-percha to be operated upon by this process is previously purified as much as possible by cutting, and pressing or kneading it in hot water. It is then exposed at a gentle heat to the action of some volatile solvent, such as essence of turpentine or benzol, but preferably of bisulphide of carbon, in which latter case no heat should be applied. One part by weight of gutta-percha dissolved in about twenty parts of solvent, yields a brown, turbid, sirupy mass, which is clarified and partly decolored by first allowing it to stand till the heaviest particles subside. The supernatant liquid, still much colored, is thoroughly purified by filtration through animal charcoal; it is then put into a still provided with a refrigerator, and if it be desired to obtain the gutta-percha in a solid state, the distillation is continued to dryness. But to obtain sheets, or to make balloons, shades, and various other forms of gutta-percha, the patentee proceeds as follows:—He takes the purified solution of gutta-percha in bisulphide of carbon, and pours a certain quantity of it into a vessel—for example, a glass cylinder stopped at one end. He then inclines the vessel, and turns it in every direction, until its sides are completely and evenly coated over internally by the solution, and then allows the excess of liquid to drain off, by holding the glass cylinder with its mouth downwards. In a short time the bisulphide of carbon volatilizes completely, leaving the inside of the glass covered with a film or thin lining of gutta percha, which loosens by its contraction in drying, and may then be readily extracted. Care must be taken, however, not to touch the cylinder with a warm hand, for the gutta-percha will adhere to the glass at the points which have been thus warmed. If the part which was in contact with the bottom, or closed part of the cylinder, be now cut off, a cylinder of gutta-percha, open at both ends, is obtained, and this being cut longitudinally, will form a sheet. Thin semi-transparent balloons, or almost any other form, may be produced in the same way, since the solution of gutta-percha will necessarily take the form of the vessel into which it is poured. When, however, the gutta-percha membrane has to be removed through a small aperture—which happens when the sirupy liquid has been poured into a bottle, or glass balloon, or mat rass—some contrivance must be resorted to, as that of introducing into the vessel a tube, by means of which the air in the vessel can be sucked out, either by the mouth, or with a syringe; the gutta-percha membrane will thus be made to collapse and recede from the sides of the vessel, after which it may be easily removed. It is evident that the more viscid the solution, the thicker will be the membrane obtained.

DYEING OF GUTTA-PERCHA, AND ITS COMBINATIONS.—A method of coloring articles formed of gutta-percha, or coated with a varnish of that substance, has been just stated, in connection with Mr. HANCOCK'S method of waterproofing and deodorizing. It is obvious that the same varnish which excludes moisture, and confines the odor of the solvent, may be mixed with colors, and will thus form a pigment of any required tint. This process may be termed painting, or color-varnishing; but in Mr. PARKES' patent for March, 1846, was embraced a claim for *dyeing* caoutchouc or gutta-percha, alone or in combination, and afterwards, when desired, treating those matters by vulcanizing agents, either in solution, or by the dry method. To dye caoutchouc, or gutta-percha, or their compounds, he boils them from a quarter to half an hour in the following preparations:—

Black.—One pound of sulphate of copper dissolved in one gallon of water, with one pound of caustic ammonia, or chloride of ammonium. Or—one pound of sulphate or bisulphate of potassa, and half a pound of sulphate of copper, with one gallon of water.

Green.—One pound of chloride of ammonium, half a pound of sulphate of copper, two pounds of caustic lime, and one gallon of water.

Purplish.—One pound of sulphate or bisulphate of potassa, one quarter of a pound of sulphate of copper, and one quarter of a pound of sulphate of indigo. Of course, the depth of color may be varied by varying the proportions of the ingredients.

Or the following colors may be applied directly:—

Blue.—Victoria blue and ultramarine.

Red.—Vermilion, carmine, or rose-lake.

Green.—Brunswick green, or acetate of copper.

Yellow.—Chrome yellow, or oxide of uranium.

White.—The color known as satin white. Mr. PARKES prefers generally to use this as a ground for the hues above-mentioned. *The coloring processes must precede the vulcanizing of the material.*

METALLIZING.—In Mr. HANCOCK'S patent of February, 1847, was embraced a method of improving the quality of gutta-percha, both in its natural and vulcanized state, by exposing it for a minute or two to the action of binoxide of nitrogen, obtained by the usual method of dissolving a metal, such as zinc, copper, or mercury, in nitric acid, or by immersing it in a boiling and concentrated solution of chloride of zinc, for a period varying from one to five minutes, according to the strength of the solution. In either case, the materials are afterwards well washed in some alkaline solution, or in soft water. Gutta-percha which has been thus treated, and whether vulcanized or not, is stated by the patentee to become exceedingly smooth to the touch, and of a lustre approaching to metallic.

SUBSTITUTES FOR GUTTA-PERCHA.—In December, 1853, a patent was granted to STANISLAS T. M. SOREL, of Paris and London, for certain improved compositions to be employed as substitutes for caoutchouc and gutta-percha. These compositions, though termed substitutes, are simply combinations of gutta-percha with other bodies, resembling in most cases those already mentioned as patented by other individuals for the same purpose. This will be at once seen from the following ingredients and proportions employed for his principal mixture:—

	Parts by weight
Colophony	2
Pitch or bitumen,	2
Resin oil,	8
Hydrated lime,	6
Water,	3
Pipe-clay, or other like argillaceous earths,	10
Gutta-percha,	12
	43

The patentee prepares the composition in a copper, heated by any suitable means. He first introduces into the vessel colophony, bitumen, or pitch, and resin oil, and agitates the mixture with a stick, or spatula, until the former two are dissolved. He then adds slacked and broken hydrate of lime of the consistence of molasses, continuing to agitate and heat the mixture, and when the latter is completely liquefied he introduces the gutta-percha, cut into small pieces. The agitation is continued till the gutta-percha is dissolved, when argil is introduced, either powdered or mixed with water, and well incorporated with the mixture. An excess of water is then added, and the whole is heated to ebullition. The matter is now separated and kneaded in water, then withdrawn from the copper and again heated, and passed several times between the rollers of a rolling machine to render it homogeneous, when it is ready to be employed.

The colophony may be replaced by other resins, as burgundy pitch, or gum-copal. The argillaceous earth may be entirely suppressed in the composition. To render the latter more tenacious, he increases the quantity of gutta-percha; and to augment still more its tenacity, and render it a little elastic, he adds a small quantity of natural or vulcanized caoutchouc, cut up, like the gutta-percha, into small pieces. To render the composition more completely waterproof, he adds about five per cent. of bees' wax or stearic acid. It may be colored with smoke-black, or other coloring matters.

Subjoined are three combinations, in the first of which the colophony is replaced by pitch; in the second, both the resin and resin oil are superseded; and in the third, pitch is replaced by coal-tar from the gas-works:—

	I.	II.	III
Pitch,	8	12	—
Resin oil,	4	—	—
Coal tar,	—	—	12
Slacked hydrate of lime,	6	6	6
Gutta-percha,	16	16	16
	34	34	34

Argil may be added to the above three compositions. They are stated by the patentee to be applicable for replacing caoutchouc and gutta-percha in their principal applications, and especially for waterproofing stuffs, and the manufacture of tubing, of driving-straps, waterproof boots and shoes, bobbins and cylinders for spinning machinery, capsules for stopping bottles, and other like articles. They may likewise be moulded for making vases, and other ornamental articles. For giving the composition greater tenacity, fibrous materials, such as cotton, wool, hemp, cow hair, and leather waste, may be added. When properly rolled into sheets, it may be lined or covered with thin sheets of natural or vulcanized caoutchouc by means of a rolling machine, or by sticking them together with a solution of caoutchouc or gutta-percha, or any other suitable adhesive agent. These double sheets may be employed for the upper leathers of waterproof boots and shoes. The soles may be either of waterproofed leather, of gutta-percha, or of wood.

ADULTERATIONS.—From the list of patents which have been given for mixing or combining gutta-percha with other substances, including caoutchouc, pitch, pipe-clay, vegetal wax, calcined bones, coal-tar, lime, sulphur, cocoa-nut shell, Portland stone, and an almost infinite variety of other materials, all of which are assumed by the respective patentees to peculiarly adapt the resulting compound for certain specified applications, it may seem unreasonable to brand as adulterations the admixture of ingredients which are added by legal sanction for certain avowed purposes. On this extreme principle even the process of vulcanizing, which imparts to caoutchouc and gutta-percha more than half their value, would be a sophistication; for it presupposes the admixture of the article with sulphur, or some of its compounds. Allowing, therefore, that gutta-percha may be too often adulterated, and deteriorated for all practical uses, under patent authority, while, on the other hand, the fact is undeniable that by certain admixtures and combinations the qualities of the compound are improved for certain purposes, the Editor will confine himself to those adulterations which are practised by the native Malays and Chinese traders, and in consequence of which an impure or inferior article is palmed on the European importer.

The fact that the native Malays often introduce stones, earth, and other impurities, into the blocks of gutta, to increase their weight, has been already noticed, and may also be left out of consideration, as these impurities are often too easily detected, to the injury of the machinery of the manufacturer. Such impurities are also readily eliminated in the process of purification. But the case is otherwise, when, as frequently happens, the gutta-percha is mixed with other gums of an inferior character. The chief trade in the article is carried on by the Chinese, who adulterate it with the valueless juice of a tree called *Getah Malabeöya*, which they import from Palembang. By this admixture various sorts of gutta-percha are obtained, which differ considerably in price. Among several samples examined by M. ADRIANI, one was in cakes of five to six inches thick, and was darker on the outside than in the interior; another was of a very loose structure, and was much contaminated with small stones, but agreed in color, which was in general a flesh-red, with the former; a third sample was white, slightly inclined to brown. This last piece had been removed as an impurity from a large block of gutta-percha, but was found to be in quality perfectly equal to the best gutta, and was afterwards rolled out in the manufactory of MUNNICH, BECKE, and Co., into sheets of the thickness of paper, for address cards for that firm. The same chemist obtained a sample of the Getah Malabeöya, imported from Palembang, and also a sample of gutta-percha adulterated with that substance. The getah, which seemed to be also an inspissated milky juice, was imported in the form of plates, of about an inch in thickness, of a greyish color, somewhat clammy to the touch, and brittle when dried. When cut, it was found of a dirty white color, and contained many impurities. Like gutta-percha, it was dissolved by chloroform. The vessel in which it was contained emitted, on being opened, a disagreeable acid smell. Treated like gutta-percha, and purified by hot water, it was much darker than the raw substance, and often quite black; the smell was equally offensive, and its consistency similar to that of wax or glaziers' putty. The gutta-percha adulterated with the getah was of a loose texture, of a more greyish color, and of a smell different from that of genuine gutta. In warm water the getah became soft and sticky; treated with boiling water, it formed a neutral milky liquid, which was precipitated by alcohol. When boiled with alcohol it became glutinous, the alcohol extracting a white fat, resembling wax and resin; ether extracted also resin. Being dissolved in chloroform and filtered, a black coloring substance remained behind, which could not be dissolved by the usual solvents, and was burnt without leaving a residue. It appeared to be nothing else but soot. The getah melts at 170°, and becomes decomposed only at a much higher temperature, when dark-colored oils are distilled off.

USES AND APPLICATIONS.—From several processes described in connection with the manufacture of gutta-percha, and from the list of patents enumerated under the head of its combinations, *et cetera*, the reader will have seen that the substance admits of a vast variety of applications; and, indeed, the mere consideration of its singular and valuable properties is sufficient to show that the only bar to its almost indefinite extension into the arts and uses of life is the considerable price of the article, arising from its necessarily limited supply compared with the great demand for it. Its chemical and other properties have been already stated, but in now proceeding to give a more extended list of its applications, it may not be out of place to remark that these will be found chiefly to depend on the following peculiarities:—

1. Its capacity of being moulded by gentle heat and pressure into any required form, and of retaining this impressed form when cold, with extreme tenacity.
2. Its pliability at common temperatures.
3. Its impermeability to water and other fluids.
4. Its power of resisting not only the solvent action of common liquids, but even the corrosive action of most acids, of caustic alkalies, and alcoholic liquors.
5. Its valuable property as an insulator or non-conductor of electricity, in which respect it ranks second to no other known substance.
6. Its singular acoustic properties, as a conductor of sound.
7. Its capacity of combining with sulphur or its compounds, and being vulcanized like caoutchouc, so as to be unaffected by considerable changes of temperature.
8. Its aptitude for uniting with various other substances in any required proportion, so as to produce

compounds combining remarkable hardness with a certain amount of elasticity.

9. Its power of receiving and retaining the sharpest and finest impressions from the die or mould.

10. Its great durability at common temperatures, and under almost all agencies.

To these properties, separately or conjointly, may be traced its peculiar fitness for the following applications, namely: For a protection to underground and submarine telegraph-wires—a purpose for which it is not less fitted by its pliancy and its resistance to moisture than by its high insulating power; for replacing the cylinder or disc of electrical machines; for insulating handles and other electrical apparatus; for tubes to convey not only cold water, but acids, alkalies, and other corrosive liquids; for bath-cisterns, buckets, bottles, or other vessels; for lining acid and alkali cisterns formed of wood; baths for photographic purposes, and different laboratory apparatus; sieves and pumps for acid and alkaline liquors; funnels, siphons, valves, and stopcocks for corrosive solutions; conversation tubes for mines, ships, warehouses, or railways; stethoscopes and other surgical instruments; driving-bands for all kinds of machinery; rollers, bobbins, *et cetera;* boot and shoe-soles—one of its most extensive applications; waterproof clogs for dyers or maltmen; horse-trappings; waterproof cases for charts, maps, arms, and such like; noiseless rings for bed and window curtains; cords for window-sashes and blinds; clothes-lines; whips; waterproof portmanteaus; hats for miners, sailors, carriers, *et cetera;* moulded objects of every description, as fancy baskets, bread-trays, ink-stands, watch-stands, clock-cases, medals, picture-frames, buttons, flower-pots, and various similar applications.

The author of the Jury Report on the manufactures from gutta-percha in the Great Exhibition, says:—It is especially in the fabrication of articles for maritime use that gutta-percha—resisting, as it does, the action of water, and especially of brine—appears to be the best adapted. Buoys of every description for anchors, nets, *et cetera*, have been made of it; sailors' hats, speaking trumpets, and the like. It may be added that even fish-nets are formed of gutta-percha cord. It will be seen from the preceding enumeration of uses, that the decorative art has also taken large advantage of the plastic properties of gutta-percha. Various articles of furniture, the prices of which are so much enhanced by carving, are capable of being reproduced by means of pressure, and thus multiplied at a comparatively low price. Writing-tables, work-baskets, *et cetera*, can be produced in gutta-percha, and thus made to combine the threefold advantage of lowness of price, elegance of form, and absence of fragility. In the London Gutta-Percha Company's Works are made every day a great quantity of mouldings, friezes, panels, leaves, and articles of every description. These, combined by the decorator, and covered with gilding, which gutta-percha takes in perfection, are, in the manufacture of picture-frames, and in the decoration of furniture, capable of superseding the carving upon wood, which is so costly, or papier-maché and carton-pierre, which present the defect of great fragility.

Bronze articles have also been reproduced in a felicitous manner. At the Great Exhibition, the West Ham Gutta-Percha Company, represented by Mr. HANCOCK, exhibited, among various other objects, a beautiful group representing a boar-hunt, covered with a metallic coating in imitation of bronze. The author of the Jury Report remarks, that the cleanness of the edges and the purity of the forms which gutta-percha receives in the mould, make it easy to understand how this substance has been found capable of being used for making galvano-plastic moulds, and how some experiments have been tried for the purpose of substituting gutta-percha in the process of stereotyping, for the metal with which at the present day the pages of illustrated books are multiplied. Stereotype plates of gutta-percha, with specimen impressions, were actually exhibited by the London Gutta-Percha Company, in connection with a large unfinished machine, intended for printing therewith on endless paper, which was also to be cut and folded before leaving the machine, the gutta-percha types not requiring the paper to be damped. It does not appear, however, that this application of gutta-percha has been brought into general use. Moulded into the form of a jawbone, it has been found capable of holding together artificial teeth, and thus advantageously superseding those settings in gold which were so costly, and which, on account of their absolute rigidity, presented much inconvenience. The solution of gutta-percha in oil of tar and other solvents, which, by their evaporation, leave the gutta uninjured, can be made use of to obtain sheets of extreme thinness, which have begun to be extensively used in surgery. But, apart from its use as a covering for submarine telegraph wires, and its common application as a substitute for leather soles, it is more especially to the manufacture of tubes and chemical utensils for the conveyance and conservation of acids, *et cetera*, that gutta-percha seems calculated to render the greatest services.

STATISTICS.—The imports of gutta-percha into the United Kingdom in 1850, amounted to one thousand two hundred and fifty tons. The prices vary, according to the supply and demand, from fourpence to one shilling and fourpence per pound—average, eightpence—showing the aggregate value of the above imports to be equivalent to ninety-two thousand five hundred and fifty pounds sterling. The article is manufactured in London, Manchester, and Liverpool.

HYDROCYANIC ACID.—*Acide prussique*, French: *Berlinerblausäure*, *Hydrocyansäure*, German; *Acidum hydrocyanicum* vel *Borussicum*, Latin.—This important compound—which, from its animal origin, has also been named *zootic acid*, and the poisonous properties of which are, unfortunately, so well known—was first isolated by SCHEELE. DIESBACH and DIPPEL, in 1704, discovered Prussian blue. Forty-eight years afterwards, MACQUER found that lime-water resolved this substance into *calx of iron*—sesquioxide—and *a combustible coloring matter*, which he could not separate, but which combined with potassa, forming *phlogisticated potassa*—ferrocyanide of potassium. GUYTON MORVEAU concluded in 1772 that this principle had acid properties. In the year 1782, SCHEELE succeeded in preparing the aqueous solution of *prussic acid*, which he said was composed of ammonia, acid of air, and phlogiston. Berthollet, in 1787, described it, in similar terms, as consisting of carbon, hydrogen, and nitrogen. Proust and Ittner discovered several of its compounds, and the latter is said to have procured anhydrous hydrocyanic acid by the action of hydrochloric acid upon cyanide of mercury, but, being unable to condense the vapor, he pronounced it to be a permanent gas. Gay-Lussac, however, in 1811, effected its liquefaction, determined the relative proportions of its ultimate elements, and led the way to the intimate knowledge and useful application of many of its compounds.

Sources and Preparation.—Hydrocyanic acid exists, ready-formed, in many vegetal substances; and is generated in many others, in which it was formerly believed to pre-exist, by the various methods which were devised for its extraction. The kernels of bitter almonds, plums, peaches, apricots, and cherries, the leaves and more tender branches of the peach, the leaves of the Portugal and cherry laurel, and many portions of other vegetals belonging to the sub-orders *Pomeæ* and *Amygdaleæ*, when steeped in water for a considerable time and then distilled, yield hydrocyanic acid. According to several authorities, amongst whom are Liebig and Wöhler, the formation of the hydrocyanic acid during the immersion of the vegetal substances in water, is caused by the action of the *emulsin* upon the *amygdalin*—both of which they contain—as a ferment, decomposing the latter into grape-sugar, bitter almond oil, and hydrocyanic acid—the latter two passing over in the subsequent distillation.

It is now generally received that it is only in the more moist of such vegetal structures that the acid is ready-formed. There have been adverse opinions with regard to its presence in the leaves of the cherry laurel; Guibourt and Lepage maintaining that it is formed during their immersion, while Winckler holds that bitter almond oil containing hydrocyanic acid does really exist in the fresh leaves in minute quantity, which he believes varies with the amount of water present, disappearing entirely when the leaves are exsiccated.

Hydrocyanic acid is produced in many ways. According to Fownes, when nitrogen gas is passed over a mixture of equal parts of pure sugar, charcoal, and carbonate of potassa in a porcelain tube at a red heat, carbonic oxide, and subsequently nitrogen, pass off; cyanide of potassium and a carbonaceous mass remaining. When Erdmann and Marchand repeated this process with pure materials, and at a moderate red heat, no cyanide was formed; and even when the temperature was raised to such a degree that vapors of potassium were carried off with the carbonic oxide, they could discern doubtful traces only: on employing carbonate of potassa containing sulphate, the presence of sulphocyanide of the alkali was evident. Wöhler states that the production of cyanide of potassium from sugar-charcoal, carbonate of potassa, and nitrogen, is indubitably ascertained, but it is required that the nitrogen should be at a red heat, and that the temperature of the tube and its contents should be such that potassium is volatilized.

Desfosses has observed, that when nitrogen gas is passed through a mixture of *wood-charcoal* and carbonate of potassa, heated to redness, a small quantity of cyanide is generated; but as wood contains albuminous matter, and its charcoal is not entirely free from it, the nitrogen might either wholly or in part emanate thence.

Gmelin, citing the experiments of Rieken,—in which carbonate of potassa mixed with charcoal obtained from the purest white sugar, and heated in a current of nitrogen gas, at a temperature sufficiently high to reduce potassium, was completely converted into cyanide of the alkali-metal; in one case so effectually that the cyanide did not even effervesce with acids—and taking into consideration the fact, that when a mixture of potassium or antimonide of potassium with charcoal is heated to full redness in a current of nitrogen, not a trace of cyanide of potassium can be detected,—concludes that this formation of cyanogen requires not only the presence of free potassium, but at the same time a temperature high enough to separate potassium from its oxide.

When blood, hoofs, horns, and many animal tissues are ignited with carbonate of potassa; when blood, fats, sugar, gum, starch, and many organic bodies, both nitrogenous and free from that element, are subjected to distillation with nitric acid; and in many other instances, and by other means, is hydrocyanic acid produced. Pereira mentions the statement that cheese, when exposed to the action of water and the sun, disengages ammonia, and when treated in this state with alcohol, yields traces of hydrocyanic acid.

Examples of the formation of hydrocyanic acid having been given, it now remains to pass on to its preparation. Many methods having this object in view have been devised; some intended to produce the acid anhydrous, others, in a dilute state. The former modes will first be noticed, commencing with that of Gay-Lussac, which is as under:—

Into a perfectly clean tubulated glass retort, introduce a quantity of finely-powdered cyanide of mercury, and then add rather less than the same weight of hydrochloric acid, having a specific gravity of about 1·2. Next adapt to the beak of the retort, in a horizontal position, a glass tube, about half an inch in diameter, and two feet in length. One third of this, at the end next the retort, is filled with pieces of marble, for the purpose of retaining any hydrochloric acid which may pass off with the hydrocyanic acid. To the remainder of the tube fragments of fused chloride of calcium are supplied, which absorb the aqueous vapor. To the outer extremity of this purification tube is adapted a small receiver, surrounded with a freezing mixture. The hydrocyanic acid is expelled by means of heat; but it is advisable not to raise this very high, as, in that case, too much hydrochloric acid might be evolved, and not only is this a source of inconvenience, but, by the disengagement of much carbonic acid from the marble, hydrocyanic acid may be carried off. The use of too large a quantity of hydrochloric acid is, for the same reason, to be avoided. The reaction in this case is thus represented:—

$$\underbrace{\mathrm{Hg\,Cy}}_{\text{Cyanide of mercury.}} + \underbrace{\mathrm{H\,Cl}}_{\text{Hydrochloric acid}} = \underbrace{\mathrm{Hg\,Cl}}_{\text{Chloride of mercury.}} + \underbrace{\mathrm{H\,Cy}}_{\text{Hydrocyanic acid.}}$$

By VAUQUELIN'S process the cyanide of mercury is carefully placed in a long glass tube, terminating, at one extremity, in a small receiver surrounded by a freezing mixture, and having attached to the other end a proper apparatus for the supply of pure dry sulphide of hydrogen; this gas, on passing over the metallic cyanide, liberates its acid, and unites with the mercury to form sulphide; thus:—

$$\underbrace{\mathrm{Hg\,Cy}}_{\text{Cyanide of mercury.}} + \underbrace{\mathrm{H\,S}}_{\text{Sulphide of hydrogen.}} = \underbrace{\mathrm{Hg\,S}}_{\text{Sulphide of mercury}} + \underbrace{\mathrm{H\,Cy}}_{\text{Hydrocyanic acid.}}$$

The whole of the cyanide of mercury may be decomposed by gently heating the tube, while the gas is still passing through it; but it is better to leave a little of the metallic cyanide undecomposed, the product of the operation being thus preserved from contamination with the sulphide of hydrogen.

The last mode of procedure which it will be requisite to describe here is that of TRAUTWEIN. Fifteen parts of finely-powdered ferrocyanide of potassium are distilled at a gentle heat with nine parts of sulphuric acid, previously diluted with an equal weight of water; the distillate is collected in a well-cooled receiver, containing five parts of pure chloride of calcium, broken into small pieces. When the hydrocyanic acid has accumulated in sufficient quantity to cover the chloride of calcium, it is poured off into a well-stoppered glass vessel. The cyanide of potassium of the ferrocyanide is decomposed as in the former two processes; thus—

$$\underbrace{\mathrm{K\,Cy}}_{\text{Cyanide of potassium}} + \underbrace{\mathrm{HO,\,SO_3}}_{\text{Sulphuric acid.}} = \underbrace{\mathrm{KO,\,SO_3}}_{\text{Sulphate of potassa.}} + \underbrace{\mathrm{H\,Cy}}_{\text{Hydrocyanic acid.}}$$

For medical purposes, hydrocyanic acid is always employed in a dilute state, and as the means for directly obtaining this are preferable and more certain than that of letting down the anhydrous acid with water, many have been devised. The London College directs that seven drachms of sulphuric acid be mixed with four fluid ounces of water, and when cooled put into a retort; next two ounces of ferrocyanide of potassium are dissolved in ten ounces of water, and added. Eight fluid ounces of water are then placed in a cooled receiver, and heat being applied to the retort, six fluid ounces of acid are distilled over. Lastly, to this dilute acid are added six more fluid ounces of water, or so much that one hundred grains of the acid are entirely thrown down by 12·59 grains of nitrate of silver. Hence, it contains two, or, more exactly, 1·92 per cent. of real hydrocyanic acid.

The dilute acid of the Edinburgh College contains, according to SQUIRE, 3·98, or, according to Dr. CHRISTISON, 3·3 per cent. of anhydrous acid. The Dublin College has not fixed the strength of the acid prescribed in its Pharmacopœia. SQUIRE represents it to contain rather more than two per cent. of dry acid.

EVERETT, in 1835, proposed an entirely different plan for at once preparing the dilute acid. Dr. PEREIRA characterises it as yielding an acid of uniform strength, and as being available when the acid is required for immediate use. It consists in decomposing forty grains of cyanide of silver, with forty minims of dilute hydrochloric acid—specific gravity 1·129—made up to a fluid ounce with water.

Dr. CLARKE has suggested another process:—

Eight and a quarter parts of cyanide of potassium are dissolved in one hundred of water, and to this solution is added another of eighteen and a half drachms of crystallized tartaric acid in twenty of water. Bitartrate of potassa is thus precipitated, while the supernatant fluid contains about 2·8 per cent. of hydrocyanic acid, together with traces of bitartrate of potassa left in solution.

Again, a known quantity of cyanide of mercury is dissolved in water, and a stream of sulphide of hydrogen passed through the menstruum, which is then removed from the metallic sulphide by filtration. VAUQUELIN directs that the excess of sulphide of hydrogen should be thrown down from the solution by means of carbonate of lead. According to BRANDE, it is difficult to obtain a clear and colorless solution by this process without the addition of a drop or two of hydrochloric acid.

COMPOSITION.—It has already been stated in the introductory portion of the present article, that BERTHOLLET ascertained that the ultimate elements of hydrocyanic acid were carbon, hydrogen, and nitrogen. GAY-LUSSAC, in 1825, verified this, and, succeeding in obtaining the acid in an anhydrous state, determined the relative proportions of its constituents, with the following results:—

	At. weight		Centesimally.
2 Eqs. Carbon,............	12	....	44·45
1 Eq. Hydrogen,...........	1	....	3·70
1 Eq. Nitrogen,...........	14	....	51·85
1 Eq. Hydrocyanic acid,....	27		100·00

Symbol:—$C_2\,H\,N = H\,Cy$.

PROPERTIES.—At ordinary temperatures, anhydrous hydrocyanic acid is a clear, limpid fluid, possessing a strong penetrating odor—similar to that evolved when bitter almonds are bruised—and an acrid, somewhat bitter taste. It faintly reddens blue litmus paper, but the tinge disappears as the acid evaporates in the air. It is so volatile, that when a drop is placed upon a glass plate, it freezes by the rapidity of its own evaporation. With water or alcohol it unites in any degree. Its specific gravity at 45° is 0·705, and at 64° 0·696. It boils at 79° or 80°. It congeals at 5° into a fibrous mass, having a great resemblance to crystallized nitrate of ammonia. SCHULTZ states that the perfectly anhydrous acid is still fluid under 0°, and that the solidification at 5° is owing to the presence of water.

Hydrocyanic acid is decomposed with facility under the influence of light, ammonia being generated, and a brown substance, not hitherto examined, deposited: this transformation is prevented by the presence of a small quantity of a mineral acid. Concentrated sulphuric, nitric, and hydrochloric acids decompose it, when water is present, into formic acid and oxide of ammonium, the elements of which it contains:—

$$\underbrace{\mathrm{C_2\,H\,N}}_{\text{Hydrocyanic acid.}} + \underbrace{\mathrm{4\,HO}}_{\text{Water.}} = \underbrace{\mathrm{C_2\,HO_3}}_{\text{Formic acid}} + \underbrace{\mathrm{N\,H_4\,O}}_{\text{Oxide of ammonium}}$$

According to PELOUZE and GEIGER, the same decomposition of hydrocyanic acid into formic acid and ammonia is produced by the action of the fixed alkalies at elevated temperatures, probably in consequence of the predisposing affinity of the latter for formic acid:—

$$\underbrace{\mathrm{C_2\,H\,N}}_{\text{Hydrocyanic acid.}} + \underbrace{\mathrm{KO}}_{\text{Potassa.}} + \underbrace{\mathrm{4\,HO}}_{\text{Water.}} = \underbrace{\mathrm{KO,\,C_2\,H\,O_3}}_{\text{Formiate of potassa}} + \underbrace{\mathrm{N\,H_4\,O}}_{\text{Ammonia.}}$$

LIEBIG has found that when hydrocyanic acid is mixed with sulphide of ammonium, and the liquid heated till its color is destroyed, sulphocyanide of ammonium is formed, and this, giving immediately a blood-red hue with salts of sesquioxide of iron, forms the basis of a most delicate test for the acid, which is said to be distinctly recognizable, even when only the three thousand nine hundred and thirtieth part of a grain is present in the solution.

With nitrate of silver, hydrocyanic acid gives a precipitate, soluble, on boiling, in nitric acid; when with potassa, then a mixture of a proto- and sesqui-salt of iron, and, subsequently, an excess of hydrochloric acid are added to it, whether it is in the dilute or anhydrous state, Prussian blue is formed.

Both the anhydrous acid and its vapor are readily combustible, burning with a ruddy flame. The vapor, according to GAY-LUSSAC, has a density of 0·9476; when mixed with oxygen, it may be exploded by the electric spark, each volume of the former requiring for perfect combustion five of the latter. The products of this metamorphosis are—two volumes of carbonic acid, one of nitrogen, and one of water:—

$$\underbrace{\mathrm{C_2\,Hn}}_{\text{Hydrocyanic acid.}} + \underbrace{\mathrm{5\,O}}_{\text{Oxygen.}} = \underbrace{\mathrm{2\,CO_2}}_{\text{Carbonic acid.}} + \underbrace{\mathrm{N}}_{\text{Nitrogen.}} + \underbrace{\mathrm{HO}}_{\text{Water.}}$$

The vapor mixed with hydrogen is, according to GAY-LUSSAC, but imperfectly decomposed by a succession of electric sparks, the gaseous compound depositing a small quantity of charcoal, and perceptibly increasing in volume. GMELIN remarks, that this expansion is not very easy to account for, unless it be due to the formation of carbonic oxide, or hydrogen arising from the presence of water.

Potassium heated in the vapor of the acid unites with the cyanogen and liberates hydrogen.

According to GAY-LUSSAC, hydrocyanic acid and hydrogen slowly produce, with oxide of copper, gaseous cyanogen and water, subcyanide of the metal probably being formed:—

$$\underbrace{\mathrm{2\,H\,Cy}}_{\text{Hydrocyanic acid.}} + \underbrace{\mathrm{2\,Cu\,O}}_{\text{Oxide of copper.}} = \underbrace{\mathrm{Cu_2\,Cy}}_{\text{Subcyanide of copper.}} + \underbrace{\mathrm{2\,HO}}_{\text{Water.}} + \underbrace{\mathrm{Cy}}_{\text{Cyanogen.}}$$

The same authority asserts, that binoxide of manganese will absorb a mixture of hydrocyanic vapor with hydrogen gas, without separation of cyanogen.

PHYSIOLOGICAL EFFECTS, *et cetera*.—Although any notice, however brief, of the physiological effects of hydrocyanic acid may appear to be irrelevant here, as belonging more properly to medicine, yet the Editor conceives that, without alluding to it, the article would not be complete, and it may have its uses. For most of the information on the subject he is indebted to Dr. PEREIRA.

Hydrocyanic acid is poisonous to the vegetal as well as to the animal kingdom. When the stems of plants, possessing irritability, are immersed in the acid, they lose this property. It prevents the milk of lactescent plants from leaving its cells, and deprives seeds of their germinating power.

Experiments have been made on animals generally, from the *mammalia* down to the *infusoria*, with hydrocyanic acid. The effects appear to have been similar in nearly every instance, the animals being convulsed, and losing sensation and voluntary motion.

According to GRAY, however, some larvæ of the *musca* remained uninjured after two or three days' immersion in the acid.

Rabbits, dogs, *et cetera*, are deprived of life by it in a few seconds, whether it is administered to them internally in the fluid form, or inhaled in the state of vapor. Even when a drop is placed on the throat or eye of a dog, death occurs in a very few moments.

It was first introduced into medicine about the year 1806 by the Italian practitioners, BORDA, BRUGNATELLI, and RASORI. Its use in England was much furthered by the investigations of Drs. A. T. THOMSON and ELLIOTSON in 1820 and the subsequent year. It has been tried as a remedial agent in many affections of the pulmonary organs, in derangements of the nervous system, in hydrophobia, as an anodyne, and as an anthelmintic, with questionable success; and it is now employed only for alleviating disorders of the stomach. The dose of course varies with the kind of acid employed. Of the acid prepared according to the London Pharmacopœia, two to seven minims may be administered. One to four minims of the acid of the Edinburgh College, or one to five minims of the Dublin preparation, are accounted a dose.

When given in medicinal doses, cautiously increased, the following effects may, according to Dr. PEREIRA, be observed:—A bitter, but peculiar taste; increased secretion of saliva; irritation in the throat; frequently nausea; disordered and laborious respiration, sometimes quick, at others slow and deep; pain in the head, giddiness, obscured vision, and sleepiness. In some instances faintness is experienced.

When administered in poisonous doses of moderate quantity, a remarkably bitter taste is experienced immediately after swallowing the acid; this is soon followed by a sensation of faintness and giddiness, with salivation, and is succeeded by tetanic convulsions and insensibility; the respiration is difficult and spasmodic; the odor of the acid may be recognized in the breath; the pupils are usually dilated, though sometimes contracted; the pulse is small and imperceptible. When recovery takes place it is usually very rapid, and the whole period of suffering seldom exceeds half an hour, though there have been exceptions, in which the symptoms have extended over several hours.

When hydrocyanic acid is taken into the human system in immoderate quantity, death supervenes so speedily that the symptoms have scarcely been observed. They are probably similar to those noticed in animals, *videlicet*, imperceptible pulse, breathing not obvious; or there may be two or three deep, hurried inspirations, insensibility, and death. Convulsions may or may not be present.

The great variation in the strength of the acid renders uncertain three points of inquiry, each in itself interesting; namely, the quantity required to produce death, the time at which it begins to operate, and the period at which it proves fatal. Peculiarities not known or understood also affect the result. Very strong acid, in large doses, begins to operate very speedily, especially if its vapor be inhaled. The diluted acid, on the other hand, sometimes does not produce any obvious effect for several minutes, and death may not occur for nearly half an hour.—*Pereira.*

The mode in which hydrocyanic acid acts on the human frame is not without interest. Dr. CHRISTISON cites the case of ROBIQUET, whose fingers were benumbed several days in consequence of their being exposed to the vapor of the acid. Hence it appears that the acid acts locally on the nerves. From the odor of the acid being exhaled from animals poisoned by it, and from the detection of it by KRIMER in the blood, it is clear that the poison is absorbed; but physiologists differ as to whether the remote effects produced by it are due to absorption. Dr. PEREIRA sums up the arguments which have been adduced in favor of this theory, as follow:—

Firstly: The acid produces no remote effects when applied either to the nerves or brain. Secondly: When applied to the tongue or stomach, it acts as an energetic poison, although the nerves of these parts were previously divided. Thirdly: That if the acid be applied to a part where circulation is arrested, the operation of the poison is prevented. Fourthly: The activity of the acid is in proportion to the absorbing powers of the part with which it is placed in contact. Fifthly: A sufficient time always elapses between its application to the body and the first symptom of its action, to admit of its operation by absorption.

The principal antidotes in cases of poisoning by hydrocyanic acid are chlorine, ammonia, cold affusion, and respiration by artificial means. Though the latter should on no account be omitted, yet the first two are universally admitted to be the most efficacious. Chlorine is given in various forms, as in very dilute aqueous solution, of which one or two teaspoonfuls may be administered at intervals. Or a weak solution of chloroxide of calcium—bleaching powder—or of chloroxide of sodium may be substituted for chlorine water. Chlorine gas largely diluted with common air may be carefully inspired by the patient. Ammonia is employed in the ordinary fluid state, largely emasculated; but much has been said in favor of the inhalation of the vapor of ammonia or its carbonate, as the preferable way of employing the volatile alkali.

ADULTERATION.—It cannot be positively affirmed that hydrocyanic acid is intentionally adulterated, though there is considerable reason to believe that it is often sold in too dilute a state. But, amongst all the methods for its preparation, there are none by which it can be prepared absolutely pure without the use of the utmost precautions in every stage of the process. Hence, when due care is wanting, deteriorating substances often find their way from the retort to the receiver in considerable quantity. Again, however careful may have been its production, it is liable to decomposition if not properly preserved; this is especially the case when, from recklessness in its preparation it contains foreign principles; for these, by their action on one another, on the acid itself, or from spontaneous decomposition, may give rise to a multiplicity of products, till ultimately the acid has completely disappeared, and there remains instead an *olla podrida* worthless to the owner, and which, if administered as a remedial agent, might be productive of the worst consequences.

Pure hydrocyanic acid is entirely volatilized by heat. Should a residue be left when it is carefully evaporated, it may consist of bitartrate of potassa, oxide of lead, cyanide of mercury, or of other substances according to the mode by which it is produced. Thus, the acid made by CLARKE's method often contains a portion of the first-named salt; while that prepared according to the directions of VAUQUELIN may be contaminated with the latter substances.

The stronger acids, as sulphuric or hydrochloric, are frequently present. In this case, litmus paper is strongly and permanently reddened; and when a mixture of cyanide of mercury with iodide of potassium—formed by commingling the concentrated solutions of these salts, when the double compound falls in white crystalline plates—is added to the suspected acid, the beautiful red iodide of mercury is deposited. This test occasions no change if the hydrocyanic acid be pure.

Sulphuric acid may be detected by the addition of chloride of barium, which occasions a white precipitate, insoluble in nitric or hydrochloric acid.

Nitrate of silver causes a precipitate of cyanide of silver; and should hydrochloric acid be present, of chloride of silver. The former—cyanide—is dissolved on the addition of boiling concentrated nitric acid, while the latter remains as a white curdy deposit.

Hydrocyanic acid containing ammonia soon acquires a brown color. When treated with a strong solution of potassa in the cold, ammonia is evolved, and may be recognized by the smell, and by the white vapors which are observable when a glass stirrer moistened with hydrochloric acid is placed in immediate contiguity with it.

The acid prepared by VAUQUELIN's process frequently contains lead. This may be detected by passing a stream of sulphide of hydrogen through the acid: if lead is present in large quantity, a brownish-black deposit is speedily formed; when the amount is small, a brownish coloration only is occasioned. Sulphuric acid will likewise throw down a white precipitate of sulphate of lead.

VAUQUELIN's acid may also hold cyanide of mercury in solution, if the current of sulphide of hydrogen were not long enough continued in its preparation. It is detected by saturating the acid with this gas, when the brown sulphide of mercury is formed.

When the hydrocyanic acid has been prepared, by distilling a metallic cyanide with sulphuric or hydrochloric acid, formic acid may be retained in solution. This acid reddens litmus more strongly and permanently than does the pure hydrocyanic acid. On dissolving suboxide of mercury in the acid, and heating the menstruum, the mercury is reduced, producing a grey cloudiness, from which, when deposited, globules of metallic mercury may be elicited by friction. According to GEIGER, if the greater part of the fluid be gently evaporated, the residue reduces suboxide of mercury with effervescence.

Should hydrosulphocyanic acid be present in hydrocyanic acid, it may immediately be discovered, by adding a salt of sesquioxide of iron, when a fine blood-red color, more or less deep, appears.

DETECTION AND DETERMINATION.—The detection of hydrocyanic acid is oftentimes of the greatest importance, especially in cases of poisoning. Of late years, chemistry has, in this respect, given evidence most important and incontrovertible.

In many instances, hydrocyanic acid may be recognized by its odor, even when in a dilute state, when surrounded by decaying organic matter, or when itself partially decomposed. According to ORFILA, this test is the most delicate one, since, he says, it gives very marked indications when those afforded by the liquid reagents are only slight. This statement, however, must be received carefully, as much is necessarily dependent on the nature of the mixture containing or supposed to contain tho acid.

The reaction of caustic potassa, proto- and sesquioxide of iron, and hydrochloric acid, upon a fluid containing hydrocyanic acid, is a valuable means of detecting the latter. The mixture under examination is saturated with caustic potassa, and a solution of a proto- and sesquisalt of iron is added. The precipitate thus formed may vary in color, according to the quantity of potassa or of the salts of iron present; sometimes being yellowish, at others blue, and again, partaking of both hues, being green. Whatever be the tint, it is immediately changed to that of Prussian blue, on the addition of a little hydrochloric acid. Care must be taken not to employ too much potassa, which would prevent the development of the Prussian blue.

Nitrate of silver also indicates with great delicacy the presence of hydrocyanic acid, causing a white flocculent precipitate, soluble in *boiling* concentrated nitric acid. The latter property distinguishes it from the chloride of silver, which it much resembles. Should further proof be required that the deposited compound is the cyanide, it may be carefully dried, introduced into a glass tube, and heated in the flame of a spirit lamp. Cyanogen gas is evolved, and this is readily combustible, burning with a purplish flame.

The discovery of LIEBIG, that when hydrocyanic acid was mixed with sulphide of ammonium, and subjected to a moderate degree of heat, a compound—sulphocyanide of ammonium—was formed, which possessed the property of giving an intense blood-red color with the sesquisalts of iron, afforded a test for hydrocyanic acid, which is equal, if not superior, to any at present known. Dr. PEREIRA remarks:—When the acid is in small quantity, and mixed with solids or fluids, partially decomposed, then a modification of this test will enable one to detect a quantity of the poison which, from its minuteness, and from the absence of the usual odor, might otherwise escape notice. This slightly varied method is as follows:—Introduce the poisoned liquid or solid into a beaker or other similar vessel, which it should fill to within half an inch of the brim. Place upon a large watch-glass, which fits with tolerable accuracy to the beaker, two or three drops of sulphide of ammonium, containing an excess of sulphur, and invert it over the liquid. In three or four minutes, the watch-glass may be removed, and the moistened spot dried, with care and very gently, over a spirit-lamp or sand-bath. A white film remains, which may be either sulphur—resulting from the evaporation of the sulphide of ammonium—or sulphocyanide of ammonium, formed by the action of hydrocyanic acid, in the suspected liquid, upon the sulphide of the volatile alkali. In the latter case, the film will have a crystalline character, which, if not visible to the unassisted eye, may be detected by means of a microscope. Further, the film, if of sulphur merely, is not affected when moistened with water, and treated with a drop of sesquichloride of iron; whereas, when it consists of sulphocyanide of ammonium, the ferruginous sesquisalt immediately occasions a blood-red color, which is discharged upon the addition of a few drops of a solution of chloride of mercury. Should the film upon the watch-glass have a yellowish color, it is probably sulphide of ammonium, in which case the iron salt will give a black precipitate of sulphide of iron, thus showing that the evaporation has not been sufficient.

It should be observed, that both the Prussian blue and the nitrate of silver tests should be applied, when the suspected substance, as in cases of poisoning, contains foreign matters upon a distillate. Thus, if the contents of a stomach are under examination, they are introduced into a tubulated retort, and one-half distilled by means of a vapor or water-bath. Should the substance be alkaline—soon known by applying red litmus paper, which is at once colored blue—it may be owing to the generation of ammonia by putrefactive decomposition, and it is advisable to introduce a few drops of sulphuric acid into the retort along with the matters to be distilled.

It has been suggested that hydrocyanic acid may be formed during the distillation of organic matters. Dr. CHRISTISON rightly remarks that this objection appears only to rest on conjecture or presumption. The Editor would advise in all cases of importance, that the sulphur test, as modified by Dr. PEREIRA, and given above, should be first resorted to, and then the other tests may be proceeded with upon the original substance or a distillate from it, as its nature may render advisable, without risk of error.

The determination of hydrocyanic acid, which now presents itself to notice, is often of considerable importance, but never more so than when it is required to know the strength of an acid for medicinal purposes. Formerly, the density and the strength of the acid were supposed to be proportional, and Dr. URE constructed a table of specific gravities and corresponding strengths; but it has since appeared that these are fallacious. He subsequently proposed the following method:—Weigh out a portion of the hydrocyanic acid, and add, by degrees, a known quantity of red oxide of mercury, agitating the menstruum after each addition, till it is no longer dissolved, and the odor of the acid has disappeared. By weighing the remaining oxide, the quantity employed is known, and since one hundred and eight parts of oxide require twenty-seven of anhydrous hydrocyanic acid for its liquefaction, the proportion of the latter is readily calculated. But Duflos has shown that the cyanide of mercury first formed is capable of taking up more oxide, even at ordinary temperatures, so that this method gives too much acid, especially if the liquid is not kept quite cool, and the addition of oxide stopped as soon as the odor of hydrocyanic acid has disappeared. Care, too, must be taken that the acid is perfectly free from hydrochloric acid, which also dissolves the protoxide of mercury. In this case, Geoghegan neutralizes the hydrochloric acid with carbonate of lime before adding the oxide.

The last-mentioned chemist has directed, for the estimation of prussic acid, that nitrate of silver mixed with a small quantity of ammonia—so that the liquid after precipitation may be rather acid than alkaline—should be dropped into a known quantity of the acid, as long as a precipitate is produced. This is collected on a previously dried and tared filter, well edulcorated, dried at 212°, and weighed. One hundred and thirty-five parts of cyanide of mercury represent twenty-seven of the anhydrous acid.

Perhaps the most elegant mode of determining hydrocyanic acid is that last suggested by Liebig, and based upon the property of cyanide of potassium of dissolving chloride of silver, so as to produce a double cyanide containing an equivalent each of the cyanides of silver and potassium. The hydrocyanic acid is supersaturated with potassa, and mixed with a few drops of a solution of chloride of sodium; nitrate of silver is then added, until a permanent precipitate is produced. The proportion of the silver in the dissolved nitrate being known, the amount of hydrocyanic acid is readily calculated, since it is in the exact proportion of two equivalents to one of the silver consumed: thus supposing eighty-five grains of nitrate to have been used, which are equivalent to fifty-four of the metal, half the latter number—twenty-seven—will be the number of grains of anhydrous hydrocyanic acid present in the weighed portion operated upon. This nice method is also applicable for the estimation of the acid in cherry-laurel water, *et cetera*.

INK.—*Encre*, French; *Tinte*, German; *Atramentum*, Latin.—Ink, according to the purposes for which it is intended, is found in different forms. Writing ink, which is of various colors, is liquid, and may be either a clear fluid, as ordinary red ink, or may consist of a finely-divided precipitate equally diffused through the menstruum, as in common black ink. Printing ink is likewise of divers hues, but has a pasty consistence. The form of ink known as *Indian*, which is employed more especially as a water-color, is in solid cakes.

The present subject will be treated of in the following order:—

1. Writing inks, which are either *colored*, as black, red, blue, green, and violet; or *sympathetic*—that is, those which are colorless when committed to paper, as also when dried, but, by the application of heat, moisture, or of some compound which may be said to act as a mordant, they become visible, and are then either permanent or fugitive; in the latter case, the ink being generally caused to reappear by again applying the suitable means.

Besides these may be noticed the lithographic *transfer* inks, some kinds of which are used with the pen, and must consequently be included under this first class.

2. *Printing Inks.*—These, in all their numerous diversities of color and consistence, will be considered with reference to the purposes to which they are applied, as for letterpress, lithographic, and copperplate printing.

WRITING INKS.—There are few chemical preparations, perhaps none, of which the benefit in civilized life is so great, or of which the use is so widely extended, as that of common writing ink: consequently, there is no compound the quality of which it is so necessary to inquire into; and yet there is perhaps no subject which, up to a comparatively recent period, has been more neglected by chemists.

Before Lewis, towards the close of the last century, directed his attention to the subject, no author appears to have particularly applied himself to inquire into the theory of the composition of ink, or to bring it to perfection. All that is to be found in the works of previous writers, consists merely of formulæ for various kinds of ink, which, being composed without any attention to chemical laws, were more or less defective: so that it may be truly said, that until the time of Lewis, the preparation of writing fluids, the properties of which it is so essential to attend to, was left entirely to chance, or to empirical prescriptions.

It is indeed true, that some good kinds of ink have been discovered by accident; but those who devised them kept their composition secret, so that the public were either obliged to purchase those inks from the inventors, or to make use of such as were inferior in quality, and more or less perishable.

Ordinary black writing ink is now made from galls, sulphate of iron, green copperas, and gum. Other substances may be and often are employed, but those just named are the only requisite, and the best materials.

The ancient inks, according to the opinions of most writers, were similar to the Indian or Chinese ink of the present day. Pliny and Vitruvius allude to it as a combination of soot or lamp-black, with glue or gum; Dioscorides even mentions the proportions of three of the former to one of the latter. To these, according to some authors, the liquor extracted from the cuttle-fish was added. When this could not be obtained, or from other causes, it is evident that some of the modern sulphurized ingredients were added by the ancients; many Greek and Roman manuscripts erased by the monks having been found to retain as much of the vitriolic principle as to become again legible on the application of chemical tests.—*Encyclopedia Britannica.*

Still, very little really definite knowledge of ancient writing inks can be obtained, and the Editor will therefore confine his attention to the modern ones.

Dr. Lewis, already mentioned, found that equal weights of galls and sulphate of iron gave an ink, which, although of a good color when used, subsequently became yellowish-brown; that as the quantity of sulphate was increased, the inks were less durable in color, and that those in which the galls predominated, were most persistent. The proportions which he deemed best were:—

Powdered sulphate of iron,.......	1 ounce.
Ground logwood,........................	1 "
Bruised galls,........................	3 "
Gum-arabic,........................	1 "
White wine, or acetic acid,................	1 quart.

He found that, although water answered for all ordinary purposes, white wine gave a deeper-colored product, and the ink made with acetic acid was still blacker. Alcohol was injurious to the hue, causing a deposition of the tinctorial precipitate. A decoction of logwood, substituted for water, improved the black both in richness and depth of tint. He directs the materials to be put into a glass, earthenware, or other non-metallic vessel, and the mixture agitated four or five times every day. In ten or twelve days it is ready for use—if placed in a warm situation, considerably earlier; but if the ink is allowed to remain on the matériel, it continues to improve for a lengthened period. When decanted, it may be kept in good order with greater certainty, if a few broken—not bruised—galls, and two or three fragments of iron, are placed in it.

Lewis preferred distilled or rain water in making ink, but spring water containing calcareous salts is better adapted for the purpose. Some remarks on this subject, extracted from Napier, have been inserted in the article Dyeing.—See Vol. I., page 584.

Ribaucourt, who devoted much attention to the manufacture of inks, and published an extended paper in the *Annales de Chimie*, in the year 1798, observes:—None of the ingredients of ink should be in excess. If there be a deficiency of galls, a portion of the sulphate of iron will not be decomposed; if, on the contrary, the galls are in excess, the ferrous sulphate will take as much as it can decompose, but the remainder will be nearly in the state of decoction of galls, subject to change by becoming mouldy, or undergoing a transmutation after the ink has been used, destroying the legibility of the writing much more completely than would be the case were the sulphate of iron present in too large quantity. He further considers it doubtful whether the principles of galls are extracted by mere maceration, and says that inks thus made always flow pale from the pen, and are never of so deep a black as those in the manufacture of which the galls have been subjected to a long-continued boiling. The following recipe was devised by Ribaucourt, as affording a good writing fluid:—

Boil eight ounces of coarsely-pulverized Aleppo galls and four ounces of thin logwood chips in twelve pounds of water for one hour, or until half the liquid is evaporated. Pass the decoction through a hair-sieve or linen cloth, and then add four ounces of sulphate of iron, three ounces of gum-arabic, one ounce of sulphate of copper, and one ounce of sugar-candy. Agitate the mixture till the whole is dissolved, and leave it at rest for twenty-four hours; then decant the ink, and preserve it in well-stopped stoneware or glass bottles.

In making good writing ink, remarks Professor Brande, the great object is to regulate the proportion of sulphate of iron to the galls. If the former be in excess, although the ink may at first appear black, it becomes subsequently brown and yellow. Hence, some time should elapse before ink is used, after the ingredients are put together, in order to be tested from time to time, and the combinations perfectly regulated. The gum is added to retain the coloring matter in suspension, to prevent too great fluidity in the writing, and to protect the organic matter from decomposition.

If the paper has been made from inferior rags, bleached by an excess of chlorine, ink deposited upon it, however good, will be ultimately discolored. An excellent product is obtained as follows:—

Boil six ounces of finely-bruised Aleppo galls in six pints of water; then add four ounces of clean and well crystallized sulphate of iron, and four ounces of gum-arabic. Keep the whole in a wooden or glass vessel, occasionally shaken. In two months, strain, and pour off the ink into glass bottles.—*Brande.*

Dr. Ure directs that twelve pounds of bruised galls be put into a cylindrical copper, of a depth equal to its diameter, and boiled, during three hours, with nine gallons of water, taking care to replace at intervals what may be dissipated by evaporation. The decoction is then to be emptied into a tub, allowed to settle, and the superstratum of liquid having been drawn off, the marc is to be drained. Some recommend the addition of a little bullock's blood or white of egg, to remove a portion of the tannin; but this abstraction, says Ure, tends to lessen the product, and will seldom be practised by the manufacturer intent upon a large return for his capital. Five pounds of gum-senegal are next dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. Five pounds of sulphate of iron are now dissolved in as small a quantity of water as possible, and added. The color darkens by degrees, in consequence of the oxidation of the iron, on exposing the ink to the action of the air; when a moderately deep tint has been obtained, it should be drawn off clear into bottles, and well corked up. Dr. Ure prefers digesting, rather than boiling, the galls.

The following prescription is given in the seventh volume of the *Pharmaceutical Journal*:—

Galls, bruised,........................	2 pounds.
Sulphate of iron,........................	5 "
Gum-arabic,........................	4 "
Water,........................	12 gallons.
Creosote,........................	2 drachms.

Boil the galls in three-fourths of the water for an hour, then strain. Liquefy the gum in twice its weight of hot water, and add it to the decoction. Dissolve the copperas in the remainder of the water, mix the liquors together, and finally stir in the creosote. It is very evident that in this recipe there is a great deficiency of galls; otherwise, the quantity of sulphate of iron should be considerably reduced. The creosote is added as a preventive of mould, for which it is most efficient. Booth gives the following formulæ:—For superior black ink, take twelve pounds Aleppo galls, four pounds sulphate of iron, three and a half pounds of gum, and eighteen gallons of water. For a fine exchequer ink, forty pounds of Aleppo galls, nine pounds of sulphate of iron, ten pounds of gum, and forty-five gallons of water. In both these cases, it is directed that the bruised galls be exhausted by three consecutive boilings, each time diminishing the quantity of water, and supplying, by fresh addition, any loss by evaporation. The copperas and gum in solution are added to the strained decoction of galls, whilst both are yet warm, and the whole is allowed to repose for several weeks, when the fluid is drawn off from the sediment. A few cloves, or some drops of creosote are added, to prevent any parasitic growth.

Reid gave, in the *Philosophical Transactions* of 1827, among many valuable observations which will subsequently be noticed in this article, the following proportions:—

Galls, bruised, ...	1 pound.
Sulphate of iron, ...	3 ounces, 64 grains.
Gum, ...	3 ounces, 64 grains.
Water, ...	3 quarts.

The galls are to be boiled with three pints of water till a quart of decoction remains; it is then poured off, the remainder of the water added, and ebullition continued until again a quart only is left. The two menstrua are then mixed, and the other ingredients dissolved in them; the whole is allowed to rest for twenty-four hours, when the fluid ink is poured off, and retained for use.

By another method, Reid makes the decoction of galls as above directed, and exposes it freely to the air for ten days, agitating it two or three times each day. By this means much of the tannin is converted into gallic acid. To each quart of the decoction, add three and a half pints of water, nine ounces of sulphate of iron, and the same quantity of gum. The deposit which forms may, after three days, be separated, when the ink is fit for use.

Again, one pound of galls is exhausted as first directed, and the tannin of the decoction changed, by exposure, into gallic acid, as in the last instance. The menstruum is then mixed with a saturated solution of logwood, freshly made by boiling a pound and a half of the chips in five quarts of water, till the quantity is reduced to seven pints; eighteen ounces of sulphate of iron, and as many of gum, are dissolved in this mixed liquid; the whole is allowed to stand for two or three days, and the ink is then decanted from the sediment.

An attempt was formerly made to prepare ink by macerating iron filings in an infusion of galls; but though the resulting liquid was of the required hue, the writing produced with it was totally devoid of permanency, and was readily washed from the paper.

Japan ink is made as other inks, but the sulphate of iron is oxidised by roasting. This ink is intensely black when written with, but the color does not retain its depth or lustre. Besides these disadvantages, it clogs the pen, and is, altogether, far from being worthy of recommendation.

Before giving the formulæ for, or notices of, inks prepared from other than the ordinary ingredients, it may be well to introduce here some remarks from a paper presented by Dr. Bostock, in the year 1830, to the Society of Arts, which, though containing perhaps a few slight inaccuracies, is indicative of no small amount of research; and embodying, as it does to a great extent, the Editor's views, he does not consider any apology for its length to be requisite. Dr. Bostock says:—

When the sulphate of iron and the infusion of galls are mixed, for the purpose of forming ink, it may be presumed that the metallic oxide enters into combination with at least four proximate vegetal principles, which constitute the bulk of the soluble portion of galls, namely, gallic and tannic acids, mucilage, and extractive matter. Two of these, the gallic acid and tannin, are more especially necessary to the constitution of ink, which is considered by some of the best chemists to be essentially a tanno-gallate of iron. It is also laid down, that the sesquioxide of iron alone possesses the property of forming the compound which constitutes black ink, and that the substance of the latter is mechanically suspended, rather than dissolved in it.

Ink, as it is usually prepared, is disposed to undergo certain changes, which considerably impair its value: of these the three following are the most important:—its tendency to moulding; the liability of the black matter to separate from the fluid, the ink then becoming what is termed *ropy;* and its loss of color, the black first changing to brown, and at length almost entirely disappearing.

Besides these, there are objects of minor importance to be attended to in the formation of ink. Its consistence should be such that it will easily flow from the pen, without being so fluid as to blur the paper, or so adhesive as to clog the pen, and to be long in drying. The shade of color is not to be disregarded; a black, approaching to blue, is generally preferred to a browner ink; and a degree of lustre or glossiness, if compatible with the due spissitude of the fluid, tends to render the characters more legible and beautiful.

With respect to the chemical constitution of ink, Dr. Bostock remarks that although, as usually prepared, it is a combination of the metallic salt or oxide with tannic and gallic acids, mucilage, and extractive matter; yet the last three of them, so far from being essential, are, without doubt, the principal cause of the difficulty which is encountered in the formation of a perfect and durable ink. He illustrated this point by a series of experiments. Having prepared an infusion of galls, a portion of it was exposed to the atmosphere in a shallow capsule, until it was covered with a thick stratum of mould; this being removed by filtration, and the proper proportion of sulphate of iron added to the clear fluid, a compound was formed of a deep black hue, which showed no further tendency to foul, and which remained for a long time without undergoing any further alteration.

Another portion of the same infusion of galls had a solution of isinglass added to it, until a precipitate was no longer occasioned; by adding sulphate of iron to the filtered liquid, a black compound was produced, which, although paler than that made from the entire fluid, appeared to be a perfect and durable ink.

Lastly, a portion of the infusion of galls was subjected to continued ebullition, by which means part of its contents became insoluble; the menstruum was filtered, and sulphate of iron added to the filtrate, producing a good and permanent ink.

Dr. BOSTOCK presumes that the three causes of deterioration in writing fluids, the fungoid growth, the subsidence of the black compound, and the loss of color, are dependent upon the operation of different proximate principles: the first change he ascribes to the mucilage; the second to the extractive matter, from the property which it possesses of forming insoluble compounds with metallic oxides; the third he believes to be owing to the tannic acid, which probably, in the first instance, forms a triple compound with the gallic acid and the iron, and that, in consequence of the decomposition of the tannin, this body is subsequently destroyed. Owing to the difficulty, if not impossibility of depriving the infusion of galls of any one of its ingredients, without, in some degree, affecting the others, the last-named authority was unable to obtain any results which could be considered decisive; but experiments led him to conclude that, in proportion as ink consists merely of the gallate of iron, it is less liable to decomposition, or to experience any kind of metamorphosis.

Dr. BOSTOCK's summary is as follows:—In order to procure an ink which may be little disposed either to mould or to deposit its contents, and which, at the same time, may possess a deep black hue not liable to fade, the galls should be macerated for some hours in hot water, and the fluid filtered; the filtrate should be then exposed for about fourteen days to a warm atmosphere, when any fungoid growth that may be observed must be removed. A solution of sulphate of iron is to be employed which has been boiled, or exposed for some time to the air, and in which there is consequently an admixture of sesquioxide of iron. If the infusion of galls be made considerably stronger than is generally directed, the ink formed in this manner will not necessarily require the addition of a mucilaginous substance to render it of a proper consistence.

Dr. BOSTOCK adds further, in the *Transactions of the Society of Arts*, that one of the best fluids for diluting ink, if it be, in the first instance, too thick for use, or if it afterwards become so by evaporation, is a strong decoction of coffee, which does not appear to occasion the decomposition of the ink, while it improves its hue, and gives it an additional lustre.

The black color produced by galls in union with sulphate of iron, although faulty from its disposition to precipitate and decompose, was, from its being the only known method of making a black tinctorial solution, the sole article used during a very considerable period for atramental purposes. To those whose chief employment consisted in writing, copying, *et cetera*, the least defect in the ink caused a more or less serious addition to their labor, and the improvements made in this fluid may, therefore, be considered as real and valuable benefits.

A semi-colored solution, such as were the old ferro-gallic inks, requiring the addition of gum to prevent the deposition of the tinctorial matter, was especially liable to thicken, and flow tardily from the pen: this in sultry weather, when evaporation is rapid, became especially irksome. The introduction of the steel pen made these imperfections more manifest, causing a greater liability in the ink to concrete and deposit its coloring matter.

Writing inks were in this state when the improvements introduced by Mr. HENRY STEPHENS of London first appeared. This gentleman, applying the knowledge of chemistry which he obtained in his studies for the medical profession, to which he once belonged, engaged in extensive and successful researches upon atramental fluids.

The first improvement introduced by him consisted of a blue liquid, which had the startling novelty of becoming intensely black in a few hours after its deposition on the paper. It had the great recommendation of perfect fluidity, and the ease with which it was transferred from pen to paper, coupled with its ready but tenacious combination with the latter, were, at that time, considered really remarkable. This now celebrated writing fluid is a tanno-gallate of iron dissolved in sulphate of indigo; the common ferro-gallic writing inks consist of a liquid in which the tinctorial matter is suspended by means of gum, while in this the color is in complete solution.

RUNGE, after endeavoring for a long time to find a black fluid possessing the properties of forming no deposit, of adhering strongly to the paper, of being unaffected by acids, and, lastly, of neither acting nor being acted upon by steel pens, succeeded after many experiments. The composition has the advantages of being very simple and exceedingly cheap. It is prepared by adding one part of chromate of potassa to one thousand parts of a saturated solution of logwood, made by boiling twenty-two pounds of logwood in a sufficient quantity of water to give fourteen gallons of decoction; to this menstruum, when cold, the chromate is gradually added, and the mixture well stirred. The addition of gum is injurious. In the preparation of this ink, it must be remembered that the chromate, not the bichromate, of potassa is employed, and great care is requisite to insure the due adjustment of the relative proportions of the ingredients used. The best way is to make the decoction of logwood, and *gradually* add to it, well stirring the mixture, as much solution of chromate as will give the desired shade.

It appears astonishing, says RUNGE, what a small quantity of chromate of potassa is required to convert a large amount of decoction of logwood into a black writing fluid; the fact is, however, certain, and care must be taken not to allow the proportion of chrome salt to exceed one part for one thousand parts of decoction of logwood, as a larger quantity exercises a prejudicial effect in destroying the tinctorial matter of the liquid, whilst, in the proportion above mentioned, a deep blue-black writing ink is formed, which, unlike the ink made with tanno-gallate of iron, is perfectly fluid, forming no deposit. This fluid possesses another advantage; the paper which has been written upon with it may be washed with a sponge, or be left twenty-four hours under water, without the marks being erased. Weak acids do not destroy the writing, nor do they even change the shade, whilst that made from galls is effaced, and the ink made with logwood and sulphate of iron is turned red.

It is especially necessary, in using this atramental fluid, that the steel pens should be well cleansed from the greasy matter with which, when new, they are always coated. This may either be done in the usual way, by moistening them with saliva, and subsequently washing them with water; or, preferably, by applying to them an alkaline solution. **Runge** used this ink for two years without his steel pens being in the least affected, either by being crusted, or clogged with solid matter, or by becoming rusty.

Professor **Traill** has proposed a formula for ink as follows:—Gluten, obtained in the ordinary way, is kept from twenty-four to thirty-six hours in water, and is then digested in acetic acid having the specific gravity 1·033 or 1·034, in the proportion of three parts of gluten to twenty parts of the acid. By the aid of a gentle heat, a greyish-white, saponaceous fluid, which may be kept for some time, is obtained. From eight to twelve grains of the finest lamp-black, and two grains of indigo, form the coloring matter for each fluid ounce of the vehicle, with which it must be thoroughly incorporated. An agreeable aroma may be communicated by digesting bruised cloves, pimento, or cinnamon, in a portion of the original acid. This ink may be used with a steel pen, but should not be left in it, and the pen should be washed after use; it is not calculated for writing on parchment.—*Edinburgh Philosophical Transactions.*

Mr. **Henry Stephens** has invented an indelible carbon ink, which, if at all equalled, is certainly not surpassed. His process is as follows:—

Take common carbonated alkali, or the potassa or soda of commerce, or ammonia, or some other alkaline compound, and mix it with resinous matter,—as shell-lac or common resin,—in about equal proportions; then add water according to the required strength of the solution, and boil the whole until the resinous substance, or the greater portion of it, has dissolved; next mix the necessary quantity of fine lamp-black with this solution. A black liquid will thus be produced, which may be mixed with other suitable colored solutions, to form an indelible ink. Such tinctorial matter as is soluble in alkali, will best assimilate with this composition.

A recipe for an indelible carbon ink, published in the year 1845, by **Herberger**, is perfectly identical with that of Dr. **Traill** just given.

Dr. **Normandy** has suggested an indelible writing ink, which cannot be obliterated or defaced by any known chemical agent. Twenty-four pounds of Frankfort black must be ground with mucilage—formed by adding twenty pounds of gum to sixty gallons of water—and the mixture strained through a coarse flannel, or passed through a funnel the tube of which is closed by a sponge; four pounds of oxalic acid are then added, together with as much decoction of cochineal and sulphate of indigo as will give the required shade.

Many substitutes for galls, in the manufacture of ink, have been suggested—principally for the sake of economy. Those of Dr. **Normandy** and M. **Girond** are most worthy of notice. The former chemist employs sumach, elm wood, elder, chestnut, beech, willow, oak, plum, sycamore, cherry, poplar wood, catechu, or any other ligneous matter or berry, or extract of vegetal substances, containing gallic acid and tannin, or either of these principles. In making ink by this method, which is patented, the bark, wood, or berry, as the case may be, is reduced to powder, and boiled with water until a sufficiently strong decoction has been obtained. The quantity of water must vary, of course, according to the sort of vegetal substance employed: thus sumach will demand more water than catechu, on account of the latter being almost wholly soluble. To the menstruum is added a certain amount of logwood, of acetate and hydrate of protoxide of copper, of sulphate of alumina and potassa, and of sulphate of protoxide of iron, in quantities which must be regulated according to the nature of the organic matter first made use of. Gum-arabic or a superior quality of gum-senegal is now added, in the proportion of eighty pounds or thereabouts for each three hundred and forty gallons of liquid; also a variable amount of sulphate. As the quantity of the ingredients must be regulated by the shade of the tint intended to be produced, it is impossible to indicate absolutely the proportions in which they are to be employed; this must be decided by the taste and fancy of the manipulator. Supposing, however, that a blue-black is desired, and that sumach is the vegetal substance to which preference is given, the annexed are the proportions for two hundred and forty gallons of the ink:—Sumach, from forty-eight to sixty bushels; logwood, about two hundredweight—the quantity slightly varying, according as new or old chip is taken; gum-arabic, from eighty to one hundred and twelve pounds; protosulphate of iron, one hundredweight; acetate and hydrate of protoxide of copper, four pounds; sulphate of alumina and potassa, thirty-seven pounds; sulphate of indigo, six pounds or more, according to the required intensity of the blue. Were catechu to be employed in this case, instead of sumach, one hundredweight would be required, the proportions of the other materials remaining the same.

The obstacles which have hitherto prevented the use of the above-named astringent vegetal substances instead of galls, are the variously-colored precipitates which they afford with salts of iron, some being quite green, others brown, while decoction of galls yields with sulphate of iron a dark purple. These hues may, however, be altered at will, by the use of sulphate of indigo in different proportions, from dark-blue to the most intense black, applicable to dyeing, staining, or writing, and which may be employed with every description of pen.

The substitute for galls, patented by **Girond** in 1825, is denominated by him, *damajavag*, and consists of an extract from the shell, wood, or sap of the chestnut tree.

One hundredweight of chestnut shells, broken into fragments, is to be immersed in from one hundred and eighty to two hundred gallons of water, in a vessel of copper or other material *except iron;* and after having been allowed to soak for about twelve hours, heat is applied, and ebullition maintained for about twelve hours. If the wood of the chestnut tree is employed, it is cut into small pieces or thin shavings, and treated in the same way.

The extract is drawn off from the boiler at the end of the time specified, and filtered through a fine sieve or cloth, after which the water is evaporated from it until it becomes of a pasty consistence, when it may be cut into cakes of any convenient size, and dried in an oven at a low temperature till hard, at which time it is ready for use.

In making ink with this substitute, it is merely necessary to reduce it to a coarse powder, and use it as galls.

One hundredweight of chestnut shells yields eight or ten pounds of the dry extract.

SCOTT, in the year 1840, patented the following method for the manufacture of ink:—

Take forty-eight pounds of logwood chips, and let them be saturated two days in soft water; then boil them in a closely-covered iron caldron, with eighty gallons of the last-named liquid, for one hour and a half, when the wood must be taken out, and forty-eight pounds of the best Aleppo galls added to the menstruum, which must be boiled for half an hour, and subsequently allowed to remain in the vessel for twenty-four hours, during which time it must be frequently agitated. When the principles of the galls have been sufficiently extracted, draw off the clear fluid into a vat, and add forty pounds of pulverized sulphate of iron; let these ingredients remain for a week, during which time they should be daily agitated; then pour in four gallons of vinegar. Next take seven and a half pounds of the best picked gum-arabic, and dissolve it in sufficient water to form a good mucilage, which must be well strained, and then by degrees be mixed with the fluid; let these stand a few days longer, then add twenty ounces of concentrated nitrate of iron. When the menstruum has attained a sufficient depth of color, it is carefully decanted from the sediment, and the following substances, each separately prepared and ground, added to it:—

First, grind half a pound of Spanish indigo by means of a muller and stone, till it is very fine, occasionally adding portions of the ink until it is made into an easily soluble paste; then take five pounds of well-washed and purified Prussian blue, which must be prepared as the indigo, except that distilled water must be employed instead of the partially-prepared writing fluid. Next take four ounces of *gas-black,*—that is, the carbon collected from the smoke of gas-burners on glass surfaces —and grind it with one ounce of the nitrate of iron. These several substances are allowed to remain for a few hours unmixed, when the whole may be incorporated with the fluid, which is daily agitated for a week. The clear ink, in quantity about eighty gallons, is then poured off for use.

The Rev. J. B. READE of Aylesbury took out patents in the year 1847 for various writing, marking, and printing inks. The first only will be here noticed; the second and third will be described in their proper places in the subsequent part of the article. The only black writing ink which he has devised, is made by mixing soluble Prussian blue of a good quality—prepared by Mr. READE's own patent, and described in the manufacture of his blue ink—with ordinary gall ink. This addition of Prussian blue makes the ink, which was already unaffected by alkalies, equally proof against acids, and a writing fluid is thus obtained which cannot, according to the patentee, be erased from paper by any common method of obliteration without destroying the tissue.

Two or three black inks now remain to be noticed, which, from the nature of the ingredients, can hardly be classed with the common varieties, and have, on that account, been reserved for description to the last. The first, and not the least important, of these is BERZELIUS' indelible ink, prepared from the metal vanadium. Vanadic acid, when combined with ammonia, thus forming a vanadate of the volatile alkali, and mixed with an infusion of galls, forms a black fluid, which, according to the inventor, is the best writing ink that can be used. The quantity of salt necessary for a perfectly black ink is so small, that, to use the great chemist's own expression, it will not be worth considering when vanadium is more generally known. The writing obtained with this ink is perfectly black. Acids do not obliterate it, though they cause the color to become blue. Alkalies, when diluted so as not to act upon the paper, do not dissolve it. Chlorine, though it destroys the black color, does not efface the writing, even when water is suffered to run over it. Though this ink cannot be said to be absolutely indelible, yet it strongly resists reagents which cause common ink to disappear. It has also the advantage of being a solution, and not merely a precipitate suspended in a fluid by means of gum, so that it flows more freely from the pen.

COATHUPE has given a formula for an ink capable of resisting the action of all the substances usually employed for effacing writing. It is prepared as follows: —Boil, in a loosely-covered tin vessel, two ounces of shell-lac and one ounce of borax with eighteen ounces of distilled or rain water, stirring them occasionally until the whole is perfectly homogeneous; filter the mixture, when cold, through bibulous paper, and mix the filtrate—in quantity about nineteen ounces—with one ounce of mucilage of gum-arabic, made by dissolving the gum in double its weight of water, and add pulverized indigo and lamp-black *ad libitum.* Seethe the whole again in a covered vessel, and agitate the menstruum thoroughly in order to effect the complete solution of the gum and the admixture of the coloring matters. This agitation is continued during the cooling of the fluid, after which it is allowed to repose for a few hours, so as to permit the deposition of the excess of indigo and carbon, when it is decanted and bottled for use.

An *indelible safety ink,* patented by WHITFIELD in 1837, is prepared in the following manner:—Four gallons of linseed oil; two of cocoa-nut oil; one gallon of good molasses; five pounds of loaf sugar; two pounds each of ground sacre seed, ground cotton seed, Venice turpentine, ivory black, Antwerp black, finely-powdered burnt horns, tartar, pulverized gum-kino, and anacardium nuts; four pounds each of very finely-powdered charcoal, dried bullocks' blood, and gum-arabic; one pound each of solution of caoutchouc, parchment-shavings, powdered seed-lac, and Indian borax; and three pounds each of Aleppo galls, pomegranate peel, fine glue, and walnut skins, all in fine powder,—are mixed and boiled in a large iron caldron. On the commencement of ebullition, the mixture is ignited with a bar of red-hot iron, and the smoke which is liberated is received into a capacious inverted cone made of the best sheet-iron. As soon as the whole of the oil is consumed, the carbon which adheres to the cone is collected and carefully preserved. The residuum is then removed from the boiler, and rubbed down on a stone slab to an impalpable powder. One pound of the carbon collected in the cone, and a similar quantity of the prepared residuum, are then mixed with a quart of the best French vinegar, two gallons of hot water, and four ounces of gum-lac, and these ingredients are then boiled for ten minutes, when one pound of Aleppo galls in fine powder, and two pounds of logwood chips are added. The mixture is stirred until cold, and is then poured into large flat pans, and exposed to the atmosphere for three weeks.

Whatever may be the qualities of this ink when manufactured, it is certainly prepared in a singular manner. A mere tyro in chemical science will at once perceive that the materials are selected and proportioned so as to form a rare *olla podrida*, while the subsequent treatment of them is, to say the very least of it, wasteful in the extreme.

Copying inks, or inks which, after having been transferred from pen to paper, and having become dry, will communicate a portion of their substance to a sheet of damped paper strongly compressed upon them, thus furnishing two, and, in some instances—by renewed application, with pressure, of clean moistened paper—even a third or fourth copy of the same manuscript, are generally prepared by adding a modicum of sugar or sugar-candy, with an increased amount of gum, to the ordinary ferro-gallic inks.

RED INK.—The red inks at present in common use are of two kinds, of which, however, there are some modifications.

The first variety is prepared by making a solution of the tinctorial matter of Brazil-wood in acetic acid, the color being *raised* by means of alum.

BOOTH gives the following formula for a red ink:—Brazil-wood, two ounces; chloride of tin, half a drachm; gum-arabic, one drachm; water, thirty-two ounces. These ingredients are subjected to continuous ebullition, until the quantity of fluid amounts to only sixteen ounces.

HEUSLER'S recipe is here given:—Boil two ounces of Brazil-wood, half an ounce of pulverized alum, and the same quantity of crystals of bitartrate of potassa in sixteen ounces of distilled water, until the fluid is reduced to one-half. Strain the liquor, dissolve in it half an ounce of gum-arabic, then mix with it a tincture made by digesting a drachm and a half of cochineal in one and a half ounce of alcohol of specific gravity 0·839.

Red inks of the second class are prepared from cochineal or carmin; the most common modification is a simple solution of the latter in an excess of ammonia, the proportions being varied according to the depth of color required. Such ink is extremely fugitive.

The following recipe is given in the *Pharmaceutical Journal:*—Place in a porcelain vessel twelve grains of pure carmin, and pour thereon three ounces of solution of ammonia; heat over a spirit-lamp for a space of from five to eight minutes, carefully regulating the temperature so that ebullition shall not occur, and to the solution thus formed, add, continually stirring, eighteen grains of powdered gum-arabic. When this is liquefied, the ink is ready for use. Drop lake may be substituted for the carmin, as being more economical.

According to **OHME**, a good red ink may be made by macerating, for two days, six drachms of powdered cochineal, and one ounce and a half of pure carbonate of potassa, with sixteen ounces of water. Four and a half ounces of bitartrate of potassa and three drachms of alum are then to be added, and the fluid heated as long as carbonic acid is evolved. After the liquid has been filtered, the contents of the filter are to be washed in one ounce and a half of water, and one ounce of alcohol is then added to the resulting fluid, as an antiseptic. For most purposes, six drachms of gum-arabic should be dissolved in each sixteen ounces of this ink; but when used as a tinctorial agent in confectionery, for which it is well fitted, the addition of gum is unnecessary.

Mr. **STEPHENS** obtains an excellent red ink from cochineal by the following method:—Add to a quantity of common carbonate of potassa, soda, or ammonia, twice its weight of crude argol in powder. When the effervescence caused by the combination of the tartaric acid of the argol with the alkaline base, thereby expelling the carbonic acid, has ceased, decant or filter the solution from the insoluble matter; to this is added, by measure, half its quantity of oxalate of alumina, prepared by dissolving damp, newly-precipitated alumina in as small a quantity as possible of a concentrated solution of oxalic acid. The mixture thus prepared is next colored, when cold, with bruised or powdered cochineal, and after standing for forty-eight hours is strained, when it is fit for use.

The Rev. J. B. **READE** took out a patent for a red ink in the year 1847. Subjoined is his mode of preparing it:—Cochineal is first boiled in successive quantities of pure water, till it ceases, or nearly so, to afford tinctorial matter. It is then subjected to ebullition with dilute ammonia, which dissolves the remainder of the tint-giving principle, leaving the animal matter nearly white. These aqueous and ammoniacal decoctions are then mixed in an earthenware vessel, and the coloring matter is then thrown down by means of the double chloride of ammonium and tin. The compound thus formed is subsequently boiled in ammonia, and iodide of tin is then added, till the required degree of brilliancy of hue is obtained; this completes the process, the degree of body required in the ink being given by an *ad libitum* addition of water. This ink, says the patentee, is greatly superior to the common solutions from peach and Brazil-wood, not only in permanent richness of color, but also in its freedom from acid, and consequent fitness for use with steel pens.

BLUE INK.—There appears to have been no true ink of a persistent blue color, until Mr. STEPHENS introduced his *unchangeable blue writing fluid.*

Reflecting upon the durable nature of Prussian blue, as well as upon its beautiful and strong contrast to white paper, Mr. STEPHENS was led into an investigation of the means of dissolving it, so as to adapt it to atramentation, while, at the same time, it might be made serviceable to the dyer; and oxalic acid was found to answer the purpose. The ink is prepared as follows:—Take Prussian blue—whether it is that of commerce, or purposely prepared by a combination of a sesquisalt of iron with ferrocyanide of potassium, is immaterial—put it into an earthen vessel, and pour upon it as much strong acid as will cover it. Hydrochloric, nitric, and sulphuric acids are equally of service; but if the latter be used, it should be diluted with a quantity of water equal to its own bulk. The Prussian blue is allowed to remain in the acid from twenty-four to forty-eight hours, or even for a more extended period; the mixture is then diluted with much water, at the same time agitating it, for the purpose of washing from it the salts of iron. When in this state of dilution, it is permitted to rest until all the color has subsided, at which time the supernatant liquid is siphoned off, and a further quantity of water added. This process is repeated until ferrocyanide of potassium no longer evinces the presence of iron by giving a blue precipitate; and also until the menstruum ceases to redden blue litmus paper, thus proving that the acid has been entirely removed. The product is then placed upon a filter, and suffered to remain until all the liquid has drained away. The Prussian blue, by this treatment, has lost a considerable proportion of its iron, and is now more readily acted upon and dissolved than in any other condition. After being gently dried, oxalic acid is added to, and carefully mixed with, the Prussian blue; cold distilled water is then poured, in small portions at a time, over the whole, making it into a dense or dilute solution, according to the depth of color required. The amount of oxalic acid may be varied according to the quantity of water used. It will be found that Prussian blue which has undergone the process of digestion just described, requires but a small modicum of acid to dissolve it. For a concentrated solution, six parts of Prussian blue—weighed before the treatment with acid—will, after the operation, be taken up by one part of oxalic acid, and a proportional amount of water. Prussian blue, in its ordinary state, will require two or three times its weight of oxalic acid; and even then, it will be liable to precipitation after standing; when deprived of a portion of its iron in the first place, by means of acid, it remains a permanent solution.

The comparative durability of the ordinary black ferrogallic ink and that made from the sesquiferrocyanide of iron—Prussian blue—may be judged of by the following:—

Black ink is a combination of a protosalt of iron with the active principles of galls; the tannogallate of iron thus produced is good whilst the metal remains as protoxide; but, as soon as the salt has passed into a higher state of oxidation, the ink has a tendency to decay; and as still more oxygen is attracted and combined, the vegetal matter is decomposed, until eventually there remains on the paper only oxide of iron of a reddish-brown hue, similar to that produced when the ink is acted upon by chlorine. If the writing is kept from the air, and all damp is excluded, the color of the ink will be unaffected for many years; but should the manuscript be placed in a damp position, the iron soon passes into the state of sesquioxide, and the vegetal portion of the ink becomes extinct.

The ink from Prussian blue has a reversed principle as regards its permanence. While the iron is in its normal degree of oxidation, the color is only partially developed, and it is not until the iron is further oxidised by means of an acid, or by exposure to the atmosphere, that the fine deep hue is fully developed. It is here that the uniform well-known tendency of the lower oxides of iron to absorb oxygen, instead of being an evil, is of positive service. As the state of sesquioxide is the true condition in which iron combines with ferrocyanogen to give Prussian blue, and as the inherent disposition of the iron is to assume this form, it is clear that the tendency of the elements is to be permanent. As a further proof of this, if writing executed with Prussian blue ink be exposed for a longer or shorter period to the action of strong light, a deoxidation of the iron occurs, and the color is to all appearance faded; but, on removing it from the influence of light, the iron reassumes the state of sesquioxide, and the color again becomes dark: this change may be repeatedly effected in the same manuscript, with an unvarying result. This repeated deoxidation by light, and the reverse action from want of solar or other rays, is generally known and well exemplified in the case of articles of external dress dyed with Prussian blue, which, being worn—and consequently exposed to the influence of strong light, not the less powerful because coming from its primary source, the sun—become pale, and lose that brilliancy for which Prussian blue, as a tinctorial substance, is so celebrated; but when these habiliments are again brought out, after being exposed for some time to darkness, the color is revivified as by magic, and is again equal to new.

On adding a solution of ferrocyanide of potassium to ordinary black ink, a blue hue results; the affinity of the iron for the ferrocyanogen being so much stronger than that which it has for the tannic and gallic acids, the latter are displaced, thereby showing the greater force of combination in the blue, over that in the black ink. Many acids are destructive of the color of the latter, but the sesquiferrocyanide of iron is unaffected by any. Even chlorine has no action upon it, except that it perhaps deepens the shade a little. Of excess of moisture and light, and of the thousand and one physical causes which operate destructively upon black ink, only one affects the preparation of Prussian blue—light, and the action of this, as has been seen, is far from being permanent.

The Rev. J. B. Reade has also patented a blue ink, which is manufactured as under:—

A solution of iodide of iron having been carefully prepared according to the usual method, a proportion of iodine amounting to half the weight already employed, is dissolved therein, and the mixture is then poured into a semi-saturated solution of ferrocyanide of potassium, employing of this salt a quantity about equal to that of the whole of the iodine used in the first-mentioned menstruum. A decomposition of the materials thus brought together immediately takes place, the ferrocyanogen of the potassium salt combining with the iron, and falling down in a solid form; while the potassium and iodine unite to form an iodide of the alkali-metal, which remains in solution, together with a slight excess of iodide of iron. The whole is placed on a filter; the retained deposit, caused by the union of the iron with the ferrocyanogen, and which is nothing more or less than Prussian blue in a soluble state, is well washed with, and is finally dissolved in water, which forms the blue ink desired.

Dr. Normandy has proposed a blue ink, which is made by operating upon Chinese blue, or ferrocyanide of iron. Three drachms of the ferrocyanide are macerated in seven ounces of water, with one drachm of binoxalate of potassa, adding one drachm of gum-arabic. A solution of tin may be added to these ingredients; the binoxalate of potassa may also be substituted by an equivalent proportion of oxalic acid.

Ohme recommends the following formula for blue ink:—Dissolve one scruple of iron in nitrohydrochloric acid—aqua regia—filter the solution, and dilute it with sufficient water to make eight ounces, which is mixed with four drachms of ferrocyanide of potassium, previously dissolved in eight ounces of water. The resulting subsidence is collected on a filter, and after the fluid has, as far as possible, been removed, the precipitate is edulcorated with pure water, until the latter passes through, having an azure tint. As soon as this occurs, the funnel and its contents are placed over a clean vessel, the filter pierced, and the blue compound washed with twenty-four ounces, by weight, of water. This latter menstruum constitutes the blue ink, the formation of which depends on the property of the precipitate to dissolve in pure water, and not in solutions of other salts.

Purple Ink.—To produce a purple-colored ink, called the *King of Purples*, Dr. Normandy recommends the following method:—To twelve pounds of Campeachy logwood, add as many gallons of boiling water; pour the infusion through a funnel with a strainer made of coarse flannel, on one pound of hydrate or acetate of copper—verdigris—finely powdered; at the bottom of the funnel a sponge is placed; then add immediately fourteen pounds of alum, and for each seventeen gallons of liquid, add four pounds of gum-arabic or senegal; let these remain for three or four days, and a beautiful purple will be produced.

Green Ink.—Klaproth directs for the preparation of green ink, that two parts of acetate of copper and one of bitartrate of potassa be boiled in eight parts of water, till the solution be reduced to half the bulk. It is then filtered through cloth, and after cooling, bottled.

Winckler has given the following recipe for a green ink:—Dissolve one hundred and eighty grains of bichromate of potassa in one fluid ounce of water; add to the menstruum, while warm, half an ounce of spirit of wine; then decompose the mixture with concentrated sulphuric acid until it assumes a brown color. The liquor is now evaporated till it is reduced in quantity to one-half, when it is diluted with two ounces of distilled water, filtered, mixed with half an ounce of alcohol, subsequently with a few drops of strong sulphuric acid, and then allowed to rest till, after some time, it assumes a beautiful green color. It is finally adapted for use by the addition of a small quantity of gum-arabic.

Ohme has devised a green ink, made by triturating one drachm of gamboge with one ounce of the blue ink invented by him, and previously noticed; but it is of little value.

Yellow Ink.—Yellow ink, according to Dr. Ure, is prepared by dissolving three parts of alum in one hundred parts of water, adding twenty-five parts of bruised Persian or Avignon berries, boiling the mixture for an hour, filtering the liquor, and dissolving in it four parts of gum-arabic.

An extemporaneous yellow ink may be made by dissolving gamboge in water, but it is by no means permanent.

Gold and Silver Inks.—Gold ink is prepared as follows:—Grind upon a porphyry slab with a muller, gold leaf and fine white honey, till the former is reduced to an impalpable powder. The paste is then carefully collected and diffused through water, which dissolves the honey, causing the deposition of the precious metal; the water must now be decanted, and the sediment edulcorated to free it from the saccharine matter. The powder exsiccated is very brilliant, and when required for use is suspended in mucilage of gum-arabic. After the writing executed with this ink is dry, it should be burnished with ivory.

Silver ink is prepared in the same manner, by substituting this metal, in leaf, for the gold.—*Ure.*

Indian or Chinese Ink consists essentially of lamp-black formed into cakes by means of some glutinous or adhesive substance, such as gum-water. The lamp-black is said to be made in China by collecting the smoke of the oil of sesamé; and M. Merimée states that the Chinese do not use glue in the fabrication of their ink, but certain vegetable juices, which render it more brilliant and more indelible upon paper. Dr. Ure remarks, that when the best lamp-black is levigated with the purest gelatin or solution of glue, it forms, no doubt, an ink of a good color, but wants the shining fracture, and is not so permanent on paper as good China ink. In the latter has been detected about two per cent. of camphor, which is supposed to improve it. On the other hand, Proust says that lamp-black, purified by potash lie, when mixed with a solution of refined glue, and dried, formed an ink which was preferred by artists to that of China. A good Indian ink may be made with ivory black, ground to a fine powder, made into a paste with weak gum-arabic water, and then formed into cakes.

Marking Ink.—The fluids for writing on linen now known are widely different from those in vogue even a few years ago. The latter always required a preparation of the tissue, previous to their application. The formulæ for a few of these are given, not so much on account of the likelihood of their being again useful, as to give an insight into their composition, thereby showing what science has accomplished even in such a limited sphere.

Marking inks are of two kinds: the first of these is applied with the pen, the second with types.

One of the older marking inks, in using which the linen required to be *pounced* or prepared, is as under:—Dissolve one hundred grains of nitrate of silver, two drachms of gum-arabic, and one scruple of sap green in one ounce of distilled water. The linen is to be wetted before applying this, with a pounce, consisting of a solution of one ounce of carbonate of soda in eight of distilled water.

GRAY directs that the ink be composed of two drachms of nitrate of silver, six drachms of water, and two of mucilage, while one ounce of carbonate of soda in sixteen of water, together with a little sap green, form the pounce. Another ink is a solution of one drachm of nitrate of silver, one of mucilage, in five drachms of distilled water, tinged slightly by means of sap green. The pounce consists of, carbonate of soda, one ounce; gum-arabic, one ounce; water, six ounces.

A form of ink known as Italian is merely terchloride of gold, the cloth being moistened before its application with a solution of chloride of tin.

The modern marking inks do not require the pouncing of the linen previous to its being written upon; but instead, a hot iron is passed over the marks, or the cloth is held near the fire, till the color has been properly developed.

REDWOOD gives the following as the requisite properties of marking ink:—

1. That it shall flow freely from the pen, and form a well-defined mark, without running or blotting.

2. That it shall not require the application of a very strong or long-continued heat, by holding the article that has been written on to the fire, or by passing a hot iron over it, to develop the required hue.

3. That the marks produced by it, when brought out by heat or by exposure to light, shall be perfectly black.

4. That it shall not injure the texture of the finest cambric.

Subjoined is a very common formula for this kind of ink:—

Six drachms of nitrate of silver are dissolved in three ounces of distilled water, and as much ammonia is added as will liquefy the precipitate which it at first occasions. A little sap-green, ivory-black, Indian ink or indigo, diffused through four drachms of mucilage of gum-arabic, form the temporary tinctorial matter, and water is added to make up the quantity to four ounces.

Many marking inks, although black when first applied to the linen, become gradually washed out, and a yellowish stain only remains. JULES GUILLER has given three recipes for marking ink, which he believes to be free from these and some other prevalent evils. They are as under:—

For the first ink, twenty-two parts of carbonate of soda are dissolved in eighty-five of distilled water, and twenty parts of pulverized gum-arabic are diffused through the menstruum. Eleven parts of nitrate of silver are then liquefied in twenty parts of ammonia, and this is commingled with the alkaline solution. The mixed fluids are next warmed in a flask, by which they become greyish-black, and partly coagulated; subsequently, brown and clear; then, when ebullition commences, very dark, and of such a consistence that it will flow readily from the pen. This ink, and that prepared from the next formula, have the advantages that no precipitates are formed in them, and that they inspissate by boiling, whereby their color becomes darker. For the second ink take,—

	Parts.
Nitrate of silver,	5
Distilled water,	12
Powdered gum-arabic,	5
Carbonate of soda,	7
Ammonia,	10

Treat these ingredients in the manner last described, and heat the resulting mixture in a flask until it has acquired a very dark tint, which is generally the case when its volume has diminished, by evaporation, about five per cent. By continuing the evaporation too long, a precipitate is occasioned in consequence of the loss of volatile alkali. The ink prepared in this manner is distinguished by producing very black characters upon linen, and is very suitable for marking with stamps or stencil-plates.

According to the third prescription, twenty-two parts of carbonate of soda are dissolved in twenty-five of distilled water; as also seventeen parts of nitrate of silver in forty-two parts of ammonia. Twenty parts of gum are then liquefied in sixty parts of water, and mixed with the soda solution, and afterwards with that of nitrate of silver, and lastly, thirty-three parts of sulphate of copper are added.

The large quantity of ammonia in this ink, says GUILLER, is accounted for by the presence of the cupreous salt. The latter might be replaced by nitrate of silver, but a much larger amount of this would be required to render the ink as dark as it is with the sulphate of copper. Whilst other marking inks have a dark-brown color, this ink possesses a rich blue. The proportions of the ingredients in these inks can be altered according to the consistency required, the uses to which they are to be applied, or the description and quality of the textile fabric on which they will be deposited.

REDWOOD'S ink, which answers all the conditions—given above—that a marking ink ought to possess, is prepared in tho following manner:—

Dissolve one ounce of nitrate of silver, and one and a half of crystallized carbonate of soda in separate portions of distilled water, and mix the solutions; collect the resulting precipitate on a filter, edulcorate it well with distilled water, and introduce it, while still moist, into a Wedgwood-ware mortar; add eight scruples of tartaric acid, and triturate the whole until effervescence has ceased: next add a sufficient quantity of ammonia to dissolve the tartrate of silver; mix in four fluid drachms of archil, four drachms of white sugar, and twelve of finely-powdered gum-arabic; and pour in as much distilled water as will make six ounces of mixture.

The essential distinction between this and ordinary inks is the use of tartrate instead of nitrate of silver.

Long after Redwood had published his formula, generously laying his invention open for public use, the Rev. J. B. Reade devised and patented two inks, the principle of which was identical with that of Redwood. Happening to meet with an ink made according to Redwood's recipe, he threatened the manufacturer with legal proceedings; but was prevented doing so by Redwood's showing with whom the invention originated. As other compounds are implied in Mr. Reade's inks, the formula for each is appended:—

The first of these, which may be used with steel pens, and which is most readily developed on the application of heat, is prepared in the subjoined manner:—Nitrate of silver is triturated in a mortar with an equivalent of desiccated tartaric acid. Water is then added, which causes the separation of crystals of tartrate of silver, nitric acid being set free. The latter is neutralized carefully by adding ammonia, which also dissolves the metallic tartrate. Gum, tinctorial matter, and water are subsequently added in quantities which may be varied at pleasure.

By this process, remarks the patentee, the nitric acid, which is essential to a good marking ink, is retained, and the tartrate of silver formed is soluble in half the quantity of ammonia ordinarily required when nitrate of silver is the basis of the ink.

The second of the inks under this patent is made as follows:—

To a portion of ink formed by the process last described, is added an ammoniacal solution of an oxide, or salt of gold. The patentee has employed for this purpose the purple of Cassius—formed by precipitating a solution of the terchloride or other salt of gold by means of a tin salt—sulphide of gold, the iodide of gold and ammonia, and also the teriodide of gold and ammonia. The last two compounds, which Mr. Reade considers to be *new*, he obtains by dissolving iodine in ammonia with application of heat; this operation must be conducted with great caution, in order to prevent the formation of that explosive compound, teriodide of nitrogen. The iodine solution thus obtained is a valuable solvent for gold. If this metal, in leaf, be placed upon it without the addition of water, a black deposition of gold is formed, which immediately dissolves; but, if the menstruum be diluted, the oxidation proceeds less rapidly, and the gold leaf assumes before solution, not a black, but a fine purple color. This salt of gold crystallizes in four-sided prisms, soluble in water. A few drops of this solution placed on a slip of glass, generally form arborescent, microscopic crystals, from which, by application of heat, the iodine and ammonia are volatilized, and arborescent metallic gold alone remains. If the heat be applied but moderately, only one equivalent of iodine is dispelled, and white crystals of iodide of ammonium and gold are left.

A *purple-red* marking ink consists of a solution of one drachm of bichloride of platinum in two ounces of distilled water. Before writing with it, prepare the linen with a pounce made by liquefying three drachms of carbonate of soda and three drachms of gum-arabic in an ounce and a half of water.

Sympathetic Ink.—By sympathetic ink is meant a fluid which, being employed in writing, does not leave a trace of color upon the paper, but which, when exposed to moisture or heat, or when washed over with some vegetal or mineral solution, or subjected to some other agency according to its nature and chemical characteristics, becomes visible, the characters being then developed in a more or less apparent manner.

Ovid mentions the method of writing with new milk, the characters being subsequently developed, even after the lapse of some time, by coal-dust or soot. The same means are proposed by Ausonius. It may be easily perceived that instead of milk, any other colorless and glutinous juice might be employed, as it would equally retain the black powder sprinkled upon it. Pliny, perceiving this, recommends the milky sap of certain plants.

Of all sympathetic inks, none, perhaps, is more remarkable than a solution of acetate of lead. The delineations made by this menstruum are rendered intensely black by means of sulphide of hydrogen—known also as hydrosulphuric acid, and as sulphuretted hydrogen—whether it be in a gaseous or liquid state. This effect, remarks Bergmann, presented itself, perhaps accidentally, to some chemist; but the discovery is not of great antiquity. The first person who gave a receipt for preparing this ink, as far as the historian just quoted could learn, was Peter Borel. In a work by him, printed in 1653, and again in 1657 at Paris, of which there were several subsequent editions, it is called a magnetic water which acts at a distance. In these days, phenomena, the causes of which were unknown, and particularly those which seemed to occur without any visible agency, were ascribed to *magnetic effluvia*. Others concealed their ignorance under what they called *sympathy*. The recipe for making these liquids, under the name of sympathetic ink, is first given by Le Mort, and that cognomen has not only been retained with reference to a solution of acetate of lead, but has also been applied to other fluids when employed for the same purposes.

Another and more beautiful sympathetic ink is that prepared from cobalt, the writing of which disappears in the cold, but appears again of a rich green color, as often as one chooses, after being exposed to a moderate degree of heat. This invention is generally ascribed, writes Bergmann, to the French chemist Hellot. He was, indeed, the first person who, after experimenting with it, made it public, but he was not the discoverer; he acknowledges that a German artist of Stolberg first showed him a reddish salt, which, when exposed to heat, became blue, and which, he assured him, was made out of Schneeberg cobalt with aqua regia—nitro-hydrochloric acid; but, if it be true that Theophrastus Paracelsus could represent a garden in winter by this invention, it must unquestionably be older.

The development of chemistry in modern times, and the consequent discovery of an immense number of chemical compounds, have given rise to an almost infinite variety of sympathetic inks. Some of the principal ones will be described:—

Black,—write with a solution of acetate of lead, or ternitrate of bismuth, and wash the writing over with an aqueous solution of sulphide of hydrogen, which causes the formation of sulphide of lead in the first instance, and of tersulphide of bismuth in the latter case. Or chloride of mercury may be used as the ink, to be developed by being placed in contact with chloride of tin; metallic mercury, in a minute state of division, being thus thrown down. A sympathetic ink, identical with common black writing fluid, consists of a solution of sulphate of iron; tincture or decoction of galls being employed as the mordant.

Blue,—employ nitrate of cobalt as the ink, with oxalic acid as a mordant—in this case oxalate of cobalt is formed; or sulphate of iron may be used for writing, which is to be washed over with ferrocyanide of potassium.

Yellow,—use chloride of antimony as the ink, and moisten the writing with decoction of galls; or inscribe the characters with subacetate of lead, and develop them by means of hydriodic acid. A dilute solution of chloride of copper forms a beautiful sympathetic ink, which is invisible until gently heated, when the letters assume a fine yellow color, which disappears as the paper cools.

Green sympathetic ink consists simply of a solution of chloride of cobalt, with a small quantity of a salt of nickel. Writing done with the colorless arseniate of potassa, and washed over with nitrate of copper, becomes beautifully green.

Purple is produced by edulcorating, with chloride of tin, writing executed with chloride of gold, the *purple of Cassius* being in this case formed.

The substances which may be employed as sympathetic inks, either *per se* or in conjunction with others, are exceedingly numerous; but they are so generally known that it is needless to describe them.

LITHOGRAPHIC WRITING INK.—There are two kinds of ink used in lithography,—that which is employed by the lithographic writer in tracing an inscription or design on paper with a view to its subsequent transference to the stone; and that which is employed in taking impressions on paper from engraved plates with a view to the same object. The composition of the latter will be stated under Printing Inks. The writing ink is composed of ingredients mixed in the following proportions:—For one and a half ounce of shellac, take two ounces of soap, three ounces of white wax, and about one ounce of tallow; add about three tablespoonfuls of a strong solution of gum-sandarach, and when ready color with lamp-black.

PRINTING INKS.—*Encre d'imprimerie*, French; *Buckdruckerfarbe*, German.—Printing ink, though of greater importance than that used for writing, has not engaged the attention of scientific men to any extent, and few works have been published respecting it. No printers of the present day make their own ink, although many add ingredients which they believe to improve the color or quality. It is an especial business, and demands considerable capital. Every manufacturer has his own secrets, both as to material and process; and by long experience alone can printing-ink makers so select and apportion the various ingredients as to adapt it to its numerous requirements.

The commonest book-ink costs eighteenpence per pound, while the usual qualities are from two shillings and sixpence to four shillings; black ink for superior work is worth five to six shillings, while for the finest carmine ink as much as thirty shillings per pound is paid. In the latter case, the value of the tinctorial matter enhances the cost; but, when the care and labor required in the preparation are taken into consideration, it is evident that it is not the mere value of the ingredients which fixes its price.

PROPERTIES.—Printing ink, as every one must be aware, is a very different composition from that used for writing. It is a soft, glossy compound, having a certain amount of adhesiveness, and becoming, by exposure in thin layers, perfectly hard and firm. Besides these properties, which always belong to it, it possesses other and varying attributes according to the numerous purposes to which it is applied. Its preparation demands not only a tolerable proportion of scientific knowledge, but also very careful manipulation; and manufacturers have found that, to produce it of good quality, both experience and deep study are requisite. The very important use for which it is designed—the registering in a permanent manner the productions of the mind—indicates some of the properties it ought to possess. The most valuable of these is durability, or the capacity to resist successfully the obliterating influence of time; and it ought, at the same time, to have brightness and depth of tint. It must be a mutable preparation, passing from the soft adhesive state to that of a perfectly hard and dry substance, and this change of condition must have a certain rate of progress, and be to some extent under control. When prepared, some time generally elapses before it is used, and during this period it ought not to alter in the slightest degree; in fact, when the air is excluded from it, it should keep for almost any length of time. During its application to the types, its solidification ought to be as slow as possible, and unaccompanied by the emission of any unpleasant or deleterious odor. It ought not to affect the soft, elastic rollers which are employed to convey it to the type or woodcut *form*, and which, unless the ink be a perfectly innocuous preparation, are liable to considerable injury. The change of state should not be accompanied by the deposition of consolidated matter in the ink, as this impedes the workman, and proves a loss to the printer.

The trying circumstances, as regards the quality of printing ink, do not end here. Having been applied, its action must be confined to a very slight penetration into the paper,—just sufficient to prevent its detachment without materially injuring the surface of the latter. It ought to dry up, in a very short space of time, to a hard, inodorous, unalterable solid.

Printing ink should, moreover, have an oleaginous character; it ought to be very glossy, and perfectly free from any granular appearance. If, on the extraction of a small portion from a mass, it leaves but a short thread suspended, it is considered good; but the best test of its consistency is the adhesion it shows upon pressing the finger against a quantity of it.

Materials.—The ingredients of ordinary printing ink are *burnt* linseed oil, resin, and occasionally soap, with various coloring matters. A slight notice of these is required.

Linseed Oil.—The best quality of oil is used, and this is purified by digesting it in partially-diluted sulphuric acid for some hours, at a temperature of about 212°, allowing the impurities to subside, and then washing away the acid with repeated additions of hot water. The oil after this treatment is pale and turbid, and, if the edulcoration is complete, there is scarcely any odor. By rest the oil clarifies, and has then a pale lemon color. It now dries much more rapidly than before. For an experiment, four drops of oil were exposed on a slip of glass: the first was ordinary Baltic linseed oil; the second was East India oil; the third and fourth were two distinct oils which had been purified by means of sulphuric acid. In the course of a fortnight, the first was colorless and rather viscid, but no skin or pellicle had formed on its surface; the second was colorless, but had no apparent viscidity; the third and fourth were not only colorless, but a tenacious film covered the surface of each.

The purified oil is now partially resinified by heat. For this purpose it is introduced into large cast-iron pots, and boiled until inflammable vapors are freely evolved. These are ignited, and allowed to burn for a few minutes, after which they are extinguished by placing a tight cover over the boiler. Ebullition of the oil is continued until, on cooling, a firm skin forms on its surface, known by placing a drop on a slate or other smooth cold material.

According to Savage,—who has written at considerable length on this subject, and whose inks gained the large medal of the Society for the Encouragement of Arts,—the linseed oil cannot be brought, however long boiled, unless inflamed, into a proper state for making printing ink. Certain it is, that by the ebullition and ignition just noticed, the original character of the oil is totally altered; it is at first turbid, but clarifies when allowed to repose; it is now viscid and more or less adhesive; it penetrates paper with difficulty; it dries much faster than when unburnt; and it has now a pyrogenous and not unpleasant odor, which soon passes off from a thin layer exposed to the air. Fragments of slightly charred bread are by some added to the boiling oil, but no marked benefit arises from such a procedure.

Other drying oils besides linseed are occasionally used, but their cost or other considerations prevent their general adoption. Resin oil is indeed pretty largely employed by some makers; but, apart from other disadvantages, its disagreeable and permanent smell prevents its entering into other ink than that intended for temporary or common printing, as newspapers, placards, *et cetera.*

Resin is an article of considerable importance in the manufacture of printing ink, since, when dissolved in the oil—after the latter has undergone ebullition and inflammation—it communicates *body* to the fluid, and the compound bears a great resemblance to Canadian balsam. For many inks, the quality of the common black resin is sufficiently good; but some require the pale, clear, transparent resin, obtained by remelting and clarifying the residue of the distillation of turpentine with water.

The Coloring Matters of printing ink demand great attention, as much of the beauty of the typography depends upon them.

Black.—The universal ingredient for this color is lamp-black. There are vast buildings, as a writer in the *Encyclopedia Britannica* remarks, appropriated to the sole purpose of burning oil, naphtha, spirit, coal-gas, *et cetera*, to produce this black, which is collected from the sides and ceilings of the chambers. It is imported from Germany and many other countries, and no expense is spared to get the most superior quality.

Other black substances are occasionally employed. Charcoal from various sources, when reduced to an impalpable powder, and mixed with the other ingredients, furnishes a deep blue-black ink that dries rapidly. Carbonized vine-stalks, wine-lies, woods of various kinds—in fact, carbonized lignin from any source, when ground sufficiently fine—sometimes a tedious and costly operation—answer well; as also does bone-black. The brown tint possessed by lamp-black is not unfrequently neutralized by the addition of blue compounds, as indigo, Prussian blue, *et cetera.*

For *red* ink, carmin, lake, vermilion, red lead—$Pb_3 O_4$—Indian and Venetian red, are employed.

A *blue* color is supplied by Prussian blue, indigo, Antwerp blue, *et cetera.*

Chromate and bichromate of lead—known respectively as lemon and orange chrome, or as chrome yellow and chrome red—yellow ochre, gamboge, and other pigments, furnish a *yellow* hue.

Green is obtained by means of arseniate of copper, or by a union of blue and yellow colors.

For *brown*, burnt sienna, umber, sepia, and mixtures of red with black, are employed.

Preparation.—In the manufacture of printing ink, the resin is dissolved in the burnt oil, in cast-iron pots or boilers, and the varnish, thus prepared, is introduced into what is termed *the mixing vessel*, which is cylindrical, and in the centre of which, bars or rods of iron, attached to a perpendicular shaft, revolve in a horizontal position. The black or other coloring matter is then added to the hot varnish, and the whole, when thoroughly mixed, is drawn off through an opening in the base of the vessel. The *pulp* is next very carefully ground, by being passed between hard stones of a very fine texture, driven by heavy machinery, the motive power being steam. Sometimes a second grinding is requisite, but this may generally be avoided by taking care that the varnish of resin and oil is clear and free from gritty particles, and that the black is in an impalpable state.

The proportions and conditions of the various ingredients vary considerably, and great experience is required before an ink can be prepared to suit any one purpose. The oil has to be rendered more viscid, by burning, in some cases than in others; sometimes the quantity or kind of resin requires to be varied; or, perhaps, different proportions of color are requisite. Newspapers printed by steam-power require an ink of less substance than that employed for book-work, which must be tolerably *stiff*. For woodcuts, the ink must not only be stiff, but very fine. The qualities of the material to which the ink is applied, furnish an additional guide in this matter: thin paper must have a soft ink, which *works clearly*, and is not too adhesive. A fine stout paper, on the other hand, will bear a stiffer and more glutinous ink; and as resin supplies these properties, so does it in a great measure communicate brilliancy, and the most perfect and splendid effects are by these means produced.

Ure gives the following directions for making printing ink:—

To one and a half gallon of linseed oil, burnt and boiled, as above described, till a portion, extracted from the pot by means of a pallet-knife and cooled, draws out between the fingers into strings of about half an inch in length—add gradually six pounds of resin. When this has dissolved, twenty-eight ounces of dry brown soap of the best quality, cut into slices, are introduced cautiously, for the combined water causes a violent intumescence. Both the resin and soap are well stirred in, and the whole is then ignited for a few moments, in order to complete the admixture of the constituents. Two and a half ounces each of ground indigo and Prussian blue, together with four pounds of the best *mineral* lamp-black, and three and a half pounds of good *vegetal* lamp-black, are placed in an earthenware pan, sufficiently large to contain the whole of the ink, and the warm varnish is then added by degrees, carefully stirring, to produce complete incorporation of all the ingredients; and the mixture is, finally, ground into a smooth uniform paste.

The two succeeding recipes are from the *Encyclopedia Britannica*, the first being that used by Baskerville and Bulmer, and giving excellent results:—

1. Dissolve a small quantity of black or amber resin in three gallons of fine old linseed oil, which has been boiled to a thick varnish, and cooled in small quantities; allow the mixture to stand for some months, so that all impurities may subside, then mix with the best lamp-black, and grind carefully.

2. One hundred pounds of nut or linseed oil are reduced by boiling and burning to one-eighth its bulk, and to the consistence of a sirup; two pounds of coarse bread and several onions (!) being thrown in to purify it from grease. Thirty or thirty-five pounds of turpentine are boiled apart, until, when the residue is cooled on paper, it breaks clean, without pulverizing. The former is poured nearly cold into the latter, and well mixed. The compound is then boiled again, a sufficient quantity of lamp-black is incorporated, and when the ink is well ground, it is ready for use.

One pound of printing ink may be made by the subjoined recipe of Savage:—

Balsam of copaiba, nine ounces; lamp-black, three ounces; indigo and Prussian blue, ground together in equal proportions, one and a quarter ounce; Indian red, three-fourths of an ounce; dry, yellow turpentine soap, three ounces: this mixture is to be ground, by means of a slab and muller, to an impalpable smoothness. It is stated that this ink possesses a beautiful color, but appears to work foul.

John Bird took out a patent for substituting a mineral found in Merionethshire and other localities, instead of lamp-black. The mineral is freed from *debris* by washing, when it becomes a very black paste; and subsequently, on drying, a fine, black, impalpable powder, composed of—

	Centesimally.
Silicic acid,	46·00
Alumina,	42·00
Carbonaceous matter,	12·00
	100·00

The preparation of printing ink with this pigment is, in other respects, according to ordinary methods.

A patent was granted in 1854 to Thomas de la Rue, by which glycerin is employed as a vehicle for making a fugitive ink, peculiarly applicable for the printing of bankers' cheques and other similar documents. For this purpose he precipitates logwood and vegetal substances, suitable for producing coloring matters, and grinds them up with glycerin to the consistency of ordinary printing ink.

The Rev. J. B. Reade's patents for printing ink are as under:—

He describes two blue printing inks: the one is made by taking the soluble Prussian blue obtained in the manufacture of his blue writing ink, and rubbing it up with oil; or, by triturating with oil the residue obtained by evaporating his blue ink.

For the second blue ink, he prepares the soluble Prussian blue with bromine instead of iodine, and diffuses it in oil.

His first *black* printing ink is made in like manner from his black writing fluid.

A second black printing ink is made by boiling chips of logwood—for which an extract of logwood may be substituted—or other dyewoods containing coloring matter and tannin, with as much proto- or persalt of iron or of copper, as will be equal to about twice the weight of the tannin contained in the wood or extract employed; a black or bluish-black precipitate is thus obtained, the blueness of which is diminished, as required by the addition of a greater or less quantity of bichromate of potassa. The whole is finally triturated with oil; a little lamp-black, or other black coloring matter usually employed in the manufacture of printing inks, being added.

Lithographic Printing Ink.—The composition of lithographic writing ink has been already given. That which is employed to take impressions on paper from engraved plates, with a view to their transference to the stone, may be composed as follows:—Tallow, wax, and soap, of each four ounces; shellac, three ounces; gum-mastic, two and a half ounces; black pitch, one ounce and a half; to which add lamp-black to color.

The Editor cannot conclude the present article without expressing his thanks to Mr. Henry Stephens, for his kindness in supplying him with information respecting writing inks; and also to Messrs. Benjamin Smith and Son—who make the ink with which this work is printed, and who have a world-wide fame for the excellence of their productions—for similar favors with regard to printing ink.

IODINE.—*Iode*, French; *Iod*, German; *Iodium*, Latin.—This body is one of those which chemists designate elements, from the circumstance, that by no means or agency at their disposal are they enabled to extract any other form of matter from it. It may be regarded as a new substance, being discovered by M. COURTOIS, manufacturer of saltpetre—nitrate of potassa—in Paris, in the year 1812–13; and of all the simple bodies which have attracted the attention of chemists, iodine seems to be the most interesting, as, since its isolation, it has never ceased to present wide fields of investigation to the chemist and physician; many of these have been diligently explored and cultivated, but still sufficient remain untrodden to keep alive that scientific interest with which iodine has been invested from the date of its discovery. It is well known that chemistry has extended her domain of research principally during the last forty years; but even anterior to that period, chemical knowledge was so far advanced that the discovery of iodine might have been expected to take place long before its announcement by COURTOIS. That this should not have been the case is the more surprising, when the wide range of its distribution is considered, and its presence, particularly in reagents which the chemists of 1800, and their predecessors, were in the habit of using and preparing in a state of comparative purity; moreover, its characteristic appearance in the form of vapor, its odor, and the remarkable reactions which it produces, render the circumstance of its having escaped observation the more striking. The discovery of iodine is interesting, inasmuch as it was not a result arrived at by unguided experiment, as in the case of many bodies which might be cited, but of patient research. The multiplied unsuccessful attempts of COURTOIS to isolate it would be tedious to relate; but some idea may be formed of his numerous experiments and failures, from the first observation he made relative to the destruction of his copper pans employed in the decomposition of nitrate of lime with the alkaline lie of the varec or kelp, till he succeeded in tracing the effect to the cause, and in preparing iodine in a very pure state from the mother waters of his various processes. This discovery was made, as already stated, in 1812, and was announced by M. CLEMENT DESORMES at the meeting of the Institute on the 29th November, 1813. At this period iodine was anxiously sought after and studied by the celebrities of the day. By degrees it came to be known that other substances besides the ashes of sea-plants contained it, and since then numerous researches have shown that iodine is one of the most widely-disseminated elements, although, it may be remarked, that its aggregate amount is comparatively small. In the mineral kingdom it is met with, combined with silver and mercury, in ores from Mexico; in Silesian galmei it is found combined with zinc; and it has been detected in species of lead ore from South America; it is contained as iodide of potassium or sodium in the nitrate of soda from Chili, and has been detected similarly combined in the rock-salt of Hall in the Tyrol. Many springs have been found to yield quantities of iodine, united, doubtless, with the alkali metals, potassium and sodium, and with magnesium; of this description are the waters of Bex, Sülze in Mecklenburg, Rolberg in Pomerania, Salz[illegible]feln in Konigsbronn, near Unna, Rehme, near Minden Schönebeck, Halle in Saxony, Dürrenberg and K[illegible], Artern and Salzungen, Schonalkalden, Salzhausen and Kreuznach, Bolcehow and Drochobycz in Galicia, Kenahwa in North America, Guaca in the province of Antioquia in New Granada. Its presence has likewise been proved in the following mineral waters; namely, in the thermal spring of Albano, in one near Sa[illegible] in Piedmont, in several salt springs near Ascoli, in the hepatic waters of Castel Nuovo d'Asti, in the hot spring of Aix in Savoy, in the Bonnington water near Leith, in Bath water, in the water from Marienbad in Bohemia, and also in the waters from Carlsbad, Heilbrunn, and Kunzig in Bavaria; in the medicinal waters of Hall in Austria, used for the cure of goitre: in the hepatic water of Trutkawice, and in the alkaline waters of Iwoniez in Galicia. Besides these, later investigations have proved its presence in several other waters of every description. A vast amount of iodine exists in the ocean; but, from the minute centesimal proportion in which it is present, DAVY, GAULTIER, FYFE, and others, failed to detect it. In the plants which grow in the sea, as well as on its shores, the iodine is, so to speak, concentrated, and consequently, when the ashes of those are submitted to the usual tests for its detection, its presence is readily manifested. The following plants were found by SARPHATI to contain iodine in the quantities mentioned:—

	Per Cent.
Fucus filum,	0·0894
" digitatus,	0·1350
" saccharinus,	0·2300
" nodosus,	—
" vesiculosus,	0·001
" saccatus,	0·124
Lorcus siliquosus,	0·142

DAVY, GAULTIER, and FYFE found iodine in the following:—*Fucus cartilagineus*, *membranaceus*, *rubens*, and *palmatus*; according to SARPHATI, it is contained in Sphærococcus crispus; he found it also in *Ulva Linza*, *pavonia*, *umbelicalis*; likewise in *Lactuca* and *Zostera marina*. *Lichen confinis*, *Statice armeria*, and *Grimmia maritima*, growing upon rocks on which sea-water has been blown by the wind, have yielded this element; but *Ramelina scopulorum*, growing in the same situation, gave no indication to DICKIE of the presence of iodine. *Pilæ marinæ* contains it; and it is obtained in large quantities from the ashes of various species of *Fucus*, *Ulva*, and other sea-plants, which constitute the *varec* of Bretagne, and the *kelp* of the Scotch and Irish. The ashes of several shore-plants, such as the different kinds of *salsola*, and such as are used for producing the *barilla* of Spain and the Sicilian *soda*, contain very little or no iodine.

The marine animals which yield iodine are:—The Common sponge, the Horse sponge, *Lapis spongiarum*, *Spongia oculata*, *Flustra foliacea*, various species of *Sertularia* and *Tubularia*, various kinds of *Rhizostoma* and *Cyana*, *Asterias rubens*, *Crognon vulgaris*, *Mytilus edulis*; oysters contain it, and likewise various species of *Dorus* and *Venus*. It is found in cod-liver oil; and the oil from the liver of the *Raja clavata* and *Raja* *balis* give indications of its presence; and from the statements of Jonas, it appears that traces of it are afforded by Scotch salt herrings. Besides these, many other substances of the animal and vegetable kingdom contain small traces of this element. Lately it has been detected in the ashes of various coals and shaly matters; and from the researches of M. Chatin and others, it has transpired that rain water, dew, air, rose leaves, *et cetera*, give to properly-regulated experiments appreciable traces of iodine.

Properties.—M. Gay-Lussac was the first who investigated and discovered the general properties of this element, being succeeded by Sir Humphrey Davy, Vauquelin, and several others. To prepare iodine, varec or kelp is exhausted with hot water, which dissolves about one half of this substance; the liquid is filtered and concentrated, and the chief part of the chloride of sodium, sulphate of soda, chloride of potassium, and other salts, is crystallized out, leaving a mother-liquor which, besides the iodide of sodium, retains other bodies in solution, such as sulphide of sodium, hyposulphate of soda, and traces of those already mentioned. This liquid is treated with sulphuric acid in a retort, when the more unstable compounds are decomposed, and sulphates of the bases produced; and on the application of a gentle heat, the iodine passes over into the condenser. In this state it is rarely pure, but is contaminated with chlorine, sulphur, and saline matters; it may be purified from these, however, by washing with water, filtering, and pressing between folds of bibulous paper, then subliming it a second time. A better method is to dissolve the iodine in alcohol, filter from any residue, and precipitate with water. The deposit collected and dried in the usual way, is pure iodine.

So prepared, it presents a bluish-black appearance, and a metallic lustre very similar to that of black-lead or specular iron ore. It is generally obtained in crystals, which are modifications of an elongated octahedron with a rhomboidal base, the primary form belonging to the right prismatic system. See Figs. 258, 259, 260, 261, 262, and 263. The finest crystals are obtained from its solution in ether, or one of hydriodic acid exposed to the air. By sublimation it is obtained in laminæ, or broad oblique tables, which, when thin, transmit light of a red color, according to Gmelin; but Payen states that the crystals which form under the microscope, and do not exceed in thickness the two-thousandth of a millimetre, or ·000787 of an inch, are without translucency. Iodine fuses at 224·6°, and boils between 347° and 356°, giving off violet vapors, which condense upon a cold surface, producing crystals. At ordinary temperatures it is subject to spontaneous evaporation in very small quantity, but which is increased when the air is loaded with moisture. When in a thin stratum, the vapor of iodine presents a beautiful rich violet shade from which its name is derived; but if examined in layers a few inches thick, it no longer presents this appearance, but rather a black mass, impervious to diffused day or candle light. Vapor of iodine is the heaviest of all known gases, being, according to the investigations of Dumas, of specific gravity 8·717, and by calculation from its atomic weight, 8·7077. Alcohol and ether dissolve it in all proportions, producing dark reddish-brown liquids; water takes up only one seven-thousandth of its weight of this element. The solvent action is increased, however, when there are other salts dissolved in the liquid, such as nitrates or chlorides. In either case a brownish liquid is formed, which, by long exposure, disappears, the iodine being transformed into iodic and hydriodic acids. It is capable of uniting with most of the non-metallic elements, producing with some —such as nitrogen—highly explosive compounds; and with others—oxygen and hydrogen—acids which are capable of neutralizing bases, and thus forming salts, many of which are very important. The mineral acids, chlorine and several other bodies, are capable of displacing and reducing these compounds of iodine, and of setting the latter free when it colors the liquid brownish-red. A characteristic and remarkable property of iodine discovered by MM. Colin and Gaultier de Claubry, is the blue coloration it affords when brought in contact with starch-paste disseminated in water. This is so delicate and characteristic, that it still remains *the* test for iodine in all investigations, affording, according to Stromeyer, a perceptibly blue tinge when not more than one four hundred and fifty-thousandth part of iodine is contained in the liquid. Kersting has latterly discovered that, by the use of a palladium salt, so small a quantity as the millionth part of iodine may be detected in a liquid. This subject will be referred to further on. The starch test should be applied with some caution, however, as a large excess of the amylaceous substance causes the blue coloration to vanish. Heat also destroys it; and hence, in testing for iodine, the liquids must be cold. This reaction is not produced by iodine when combined with other bodies; and, consequently, when such combinations of iodine are to be examined, they should be decomposed by some strong mineral acid—sulphuric or nitric, which contains a little nitrous acid.

Fig. 258.

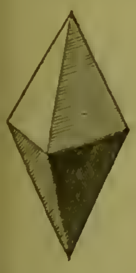


Fig. 259.

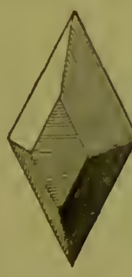


Fig. 260.

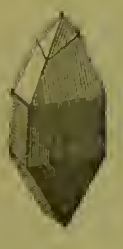


Fig. 261.

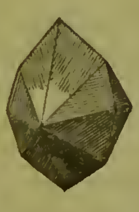


Fig. 262.

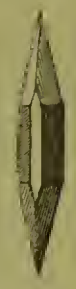
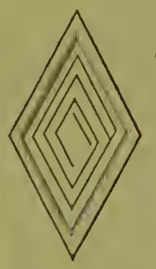


Fig. 263.



Iodine is a most valuable therapeutic agent, and, as such, was first brought into notice by Coindet, a distinguished physician of Geneva, who found it a most effectual remedy for goitre. Its application is very frequent, more especially in diseases of the skin, and for eradicating glandular enlargements, indurations, thickening of membranes and tumours, as well as in several other ailments. When applied to the skin, the cuticle becomes colored of an orange yellow, but this disappears after a short time. Iodine, in considerable doses, acts as an irritant poison, although to be fatal it must be exhibited in large quantities. In the event of poisoning by this element, the pump and copious libations of amylaceous liquids should be resorted to.

MANUFACTURE.—The atomic weight of iodine has been estimated by BERZELIUS as 126; its chemical symbol is I.

Iodine has been a subject of manufacturing industry almost from the time of its discovery; and the first to prepare it on the large scale was the discoverer, but more as a *dernier ressort*, than for the sake of the advantages which it then offered. It has been stated in the foregoing, that COURTOIS was actively engaged in the manufacture of saltpetre, in which business he had invested the whole of his money; but on the throwing open of the French ports for foreign products, immense quantities of nitrate of potassa arrived from India, which at once superseded the old nitre beds, and by so doing ruined COURTOIS. In this dilemma he tried to extricate himself by manufacturing iodine; but the consumption of the article being at this time very limited, and the process of its manufacture being circuitous, rendered the enterprise an unsuccessful one. It was prosecuted, however, after COURTOIS by MM. COURNERIE of Cherbourg, in the North-East of France, who are the oldest manufacturers after the discoverer. With its extended application, as well in medicine as in printing, and latterly in photography, others were induced to turn their attention to the subject, and now several manufacturers of the article may be found, among whom may be mentioned Mr. WHITELAW of Glasgow, and Mr. JOHN WARD of the county Donegal, Ireland.

The course pursued in its manufacture is simple. The several *fuci* and *algæ* which contain it, are collected by inhabitants of places adjacent to the sea-shore, and dried in the air, after which shallow rectangular pits are dug wherein the dried material is burned. The semi-vitrified ash that remains is broken up by sprinkling a little water upon it whilst hot. This is the *kelp* of the Scotch and Irish, and is the same as the *varec* of the Continental producers; it is purchased by the several manufacturers, in order to extract from it the iodine and other salts. For this purpose it is reduced to a coarse powder, which is placed in rectangular filters, having an inner perforated bottom of sheet-iron. These are arranged two and two, to the number of six pairs, so that whilst the one is being filled, the other is working. Water is let in upon the powder at the furthest end, till it has risen a few inches above the solid matter; and after allowing it to remain for a short time, the tap in the false bottom is opened, and the liquor drawn off as it slowly percolates through the mass.

From the receptacle in which the solution collects, it is raised by means of a pump to the second pair of filters, where it is allowed to act upon the powdered material as in the preceding instance. In the same manner the lie which is run off from each pair of filters is pumped on to the next pair, the matter in which it partly exhausts; thence it is removed to the others, and so on, till it has traversed the entire range. The solution thus obtained has a density of 1·257, and contains, for the most part, chlorides of sodium and potassium, with the iodides and bromides of these alkalies. After drawing off this first solution, the washing of the residuary mass in the filters is continued, using only as much water for this purpose as will afford a lie of 1·145 density. This is added to the other liquor, and the whole is evaporated in a series of three boilers, so disposed that the cold liquor flows into the first of the series, thence to the second, and is finally concentrated in the third, which is directly over the fire. Fig. 265 gives a longitudinal sectional view of the deposition of the evaporating pans, and Fig. 264 a transverse one.

Fig. 264.

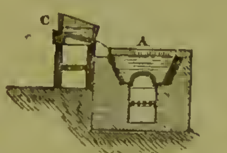
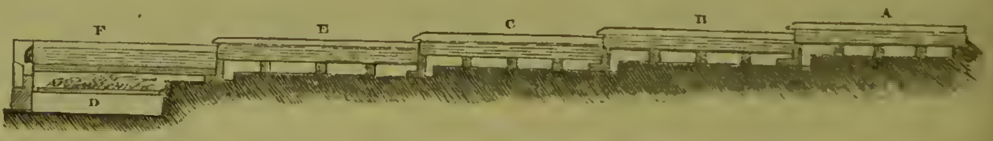


Fig. 265.



In the former of these, the pans are indicated by A, B, C, E, and F, the latter being situated over the fire, D, the flue from which passes under each in succession. After the evaporation has reduced the liquid to a density of 60° Twaddell, or 1·30 specific gravity, the chloride of sodium and sulphate of soda crystallize out in the heat, and are separated by a ladle, and thrown into an inclined drainer, C—Fig. 264—the drainings returning to the pan. When no more salt is deposited at this density, the fire is slackened, and the contents of the boiler allowed to repose for some time previous to siphoning off into wooden crystallizers lined with lead. By this a further quantity of chloride is separated in the pan, and the sulphates which are still retained are deposited in the coolers as incrustations on the sides and bottom. After removing these, and permitting the menstruum to repose for some time longer, a crop of crystals of chloride of potassium is obtained. The period allowed for the formation of the latter deposit extends to about five days, at the termination of which, the chloride of potassium is found in large crystals at the bottom of the vessel. The mother-liquor is again pumped back into the evaporators, and reduced to 68° Twaddell, at which degree, sulphate of soda, chloride of sodium, and carbonate of soda deposit. It is customary to add sulphuric acid to the liquid in the first stages, to neutralize the carbonate of soda; the quantity of the latter which the kelp affords —about two per cent.—being thought too small to be separated from the other salts. When this is done, only sulphate of soda and chloride of sodium separate after the second concentration. The crystalline mass is then removed, and the liquor left to part with a further quantity of chloride of potassium, as in the preceding case. At this stage the mother-liquor is retained for further treatment, which will be presently described. The semi-exhausted mass is further treated with water fractionally, till the solution marks 1·073; and the liquor is treated in the same manner as the first, only in a separate set of evaporators. As this contains more alkaline sulphates than the forementioned, and less chlorides, the crystallizations are effected much more readily, and when brought to about the same degree of concentration, the mother-lie, after the crystals have been deposited, is added to that from the first affusions. Finally, the washings of the residuary mass are continued till the whole of the soluble matters are removed; these weak solutions are advantageously used to exhaust fresh portions of the kelp.

The kelp may be economically edulcorated by an arrangement such as that represented in Fig. 266, in which the parts, A, B, C, D, and E, are a number of rectangular plate-iron boxes, placed in gradation one step above another. Only five are represented in the figure, but, if need be, a greater number may be employed. The last of these vases is a cast-iron wagon of double the size of the others, at the level of the rim of which a cast-iron plate, K, is placed in an inclined position, so that any liquid falling upon it may flow into the tank. By means of a pipe connected with A, at about six inches from its bottom, and which rises to the level of the next vessel, the liquid in A may be drawn over into B, which is similarly connected with the next, C, and so on to the vat, F, which, also by means of stopcocks, yields its contents to a series of plate-iron pans placed in gradation, like the others. The kelp or varec to be exhausted is put in small pieces into baskets of plate-iron, perforated in the manner of a skimmer, which are then introduced into the vats filled with water, by two men, who lift them by a wooden pole which passes through rings in the rim of the cylinder. After remaining in the first vat for the space of half an hour, they are transferred to the next vat, and their place replenished with two others, charged with fresh material. The same process takes place every half hour till the top wagon, A, contains two pair, at which stage those which have remained in it during an hour are taken out, and placed upon the inclined plate, K, to drain. At each succeeding half hour the transferring and charging takes place as before, the exhausted matter in the drained hampers being carried to the waste-heap. From the time, however, that the latter takes place, a portion of water, about double the volume of the perforated cylinder, is drawn off from the lower, and its place supplied from the next above it; the others in succession borrow from their superiors to the top one, which is replenished with water from the tank pipe. In this way, rapid and perfect exhaustion is insured, whilst the liquor which is drawn from E to the *settlers*, F F, has always a uniform strength. After the matter which had been retained mechanically in the liquid has deposited in F F, the lie is drawn off to the first of the evaporating pans which have been already mentioned, for concentrating the solution, in order to remove the sulphates and chlorides contained in it before recovering the iodine. Sometimes at this stage, especially when the ebullition has been quickly carried on, the chlorides and other salts which separate are in such small crystals, that they pass through the skimmer, and cannot be removed from the solution; hence, when the alkaline salts in kelp are procured for useful applications, there is considerable difficulty in their subsequent purification, for the sulphates and chlorides deposit promiscuously in the crystallizing pans. In order to have the separation as perfect as possible, Payen recommends a boiler such as that depicted in the drawing—Fig. 267—and indicated by A, having a fire beneath at B, and at the side an inclined case, F, from which the crystals are permitted to drain into the pan. A hemispherical vessel, C, of plate-iron, perforated at the sides, and resting on the walls of the pan, A, is placed in the liquid when near the point of ebullition. This vessel can be lifted out when necessary, by means of a chain, passing over pulleys, and attached to the basin at one end by branching chains, the other being equipoised by a weight. Ebullition of the contents of A soon takes place, and the liquid being put into violent commotion, carries the small crystals about; but as they gravitate, they fall in the centre, owing to the absence of an upward current, and are received in the vessel, C, in which they are easily removed.

Fig. 266.

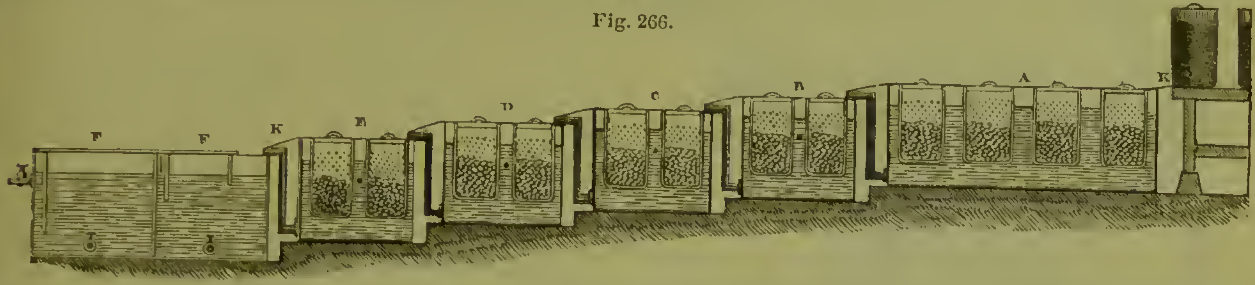
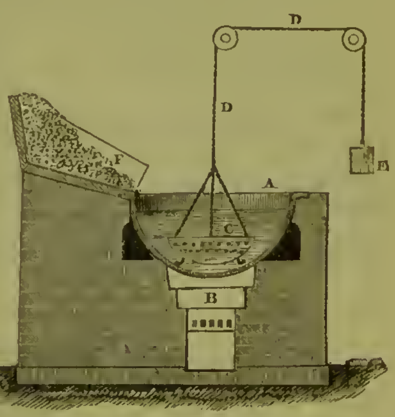


Fig. 267.



Whatever course is pursued to separate the mother-liquor from the salts, it generally happens that, in addition to the alkaline iodides and bromides, sulphide of sodium, hyposulphite of soda, with notable quantities of chlorides, are present in the solution, and which, owing to their solubility, cannot be removed. To obtain the iodine, the Scotch manufacturers add to the liquid a seventh of its volume of strong sulphuric acid, specific gravity 1·845, and, having agitated the whole, leave it to repose from thirty-six to forty-eight hours. During this period the sulphurous compounds are decomposed, sulphates being produced, whilst sulphide of hydrogen and sulphurous acid pass off, and sulphur becomes precipitated. At the end of this time the liquor is put into a retort which is adapted to a series of receivers, and heated to 140°. Having reached this temperature, a quantity of dry powdered binoxide of manganese is introduced through a tubulure in the head of the still, and the expulsion of the iodine effected at a temperature bordering on ebullition.

The chemical change which takes place in the course of the decomposition of the iodides by the sulphuric acid and binoxide of manganese, may be indicated thus:—

$$\underbrace{\mathrm{Na\,I}}_{\text{Iodide of sodium.}} + \underbrace{\mathrm{HO,\,SO_3}}_{\text{Sulphuric acid.}} + \underbrace{\mathrm{Mn\,O_2}}_{\text{Binoxide of manganese.}} =$$

$$\underbrace{\mathrm{NaO,\,SO_3}}_{\text{Sulphate of soda.}} + \underbrace{\mathrm{MnO}}_{\text{Protoxide of manganese.}} + \underbrace{\mathrm{HO}}_{\text{Water.}} + \underbrace{\mathrm{I}}_{\text{Iodine.}}$$

In this equation the oxygen from the manganese is represented as displacing the iodine, whilst the soda that is produced enters into combination with the sulphuric acid. Or it may be assumed that the binoxide of manganese, by acting upon the chlorides present under the influence of the excess of sulphuric acid, liberates chlorine, which in turn displaces the iodine thus:—

FIRST DECOMPOSITION.

$$\underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} + \underbrace{\mathrm{Mn\,O_2}}_{\text{Binoxide of manganese.}} + \underbrace{2\,(\mathrm{HO,\,SO_3})}_{\text{Sulphuric acid.}} =$$

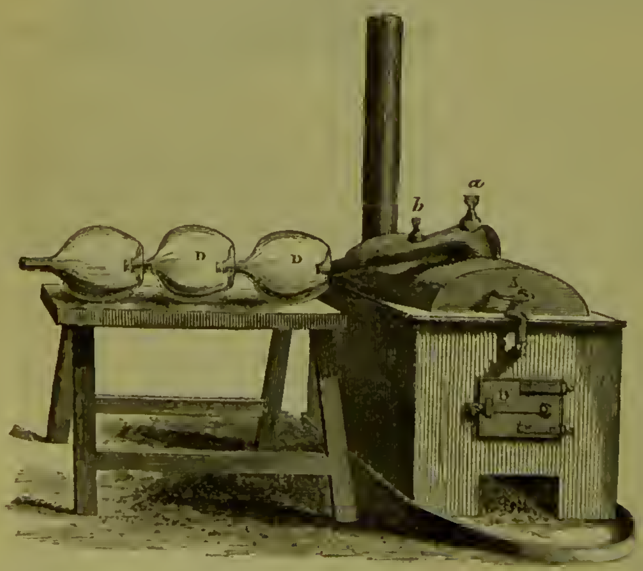
$$\underbrace{\mathrm{NaO,\,SO_3}}_{\text{Sulphate of soda.}} + \underbrace{\mathrm{MnO,\,SO_3}}_{\text{Sulphate of manganese.}} + \underbrace{\mathrm{Cl}}_{\text{Chlorine.}}$$

SECOND DECOMPOSITION.

$$\underbrace{\mathrm{Na\,I}}_{\text{Iodide of sodium.}} + \underbrace{\mathrm{Cl}}_{\text{Chlorine.}} = \underbrace{\mathrm{Na\,Cl}}_{\text{Salt.}} + \underbrace{\mathrm{I}}_{\text{Iodine.}}$$

The distillatory apparatus employed is shown in Fig. 268, in which A is the still placed on an enclosed sand-bath over the fire, the door of which is shown at B. The head or capital of the retort is usually of lead, and is furnished with two apertures, *a* and *b*, which are closed with stoppers. To the neck of the retort a series of spherical glass condensers, D D, are adapted, each of which has two apertures in its axis, one of which is drawn out so as to connect it to the next, as shown in the drawing.

Fig. 268.



After charging the retort, as already directed, with the liquor, and raising the temperature to about 140°, the peroxide of manganese is added in small portions through the stopper, *a*, and the temperature raised nearly to boiling; all the orifices and joinings being previously secured with the stoppers and pipe-clay, or other luting. The iodine passes over, and is collected in flakes in the receivers. The process is examined from time to time by opening the stopper *b*, and when the passage of iodine vapors slackens, more manganese—and acid, if necessary—are introduced through the stoppered aperture *a*, and the operation conducted till the whole of the iodine has separated. Such is the method pursued by Mr. WHITELAW of Glasgow, with this slight difference: he adds only an eighth part of sulphuric acid gradually to the liquor in a leaden boiler, and allows the sulphate of soda to crystallize out before introducing it into the still. It is important to retain the temperature at which the distillation proceeds at 212°, or nearly so, for at higher heats the iodine is liable to pass over as chloride.

Sometimes, when the process is conducted in the manner described above, cyanide of iodine is produced and is found in the third receiver in white needle-shaped crystals. The residue in the retort still retains some iodine in the form of iodide of lead and sodium. This can be recovered by the method proposed by SOUBEIRAN; namely, the addition of sulphate of copper, by which an iodide of copper is formed. The precipitate is filtered, and the filtrate, which still retains some iodine, treated with a further quantity of the cupreous salt and iron filings, when another interchange takes place, and a further precipitation of iodide of copper occurs. The first of these changes may be expressed thus:—

$$\underbrace{\mathrm{Na\,I}}_{\text{Iodide of sodium.}} + \underbrace{\mathrm{Pb\,I}}_{\text{Iodide of lead.}} + \underbrace{2\,(\mathrm{Cu\,O.\,SO_3})}_{\text{Sulphate of copper.}} =$$

$$\underbrace{\mathrm{Na\,O,\,SO_3}}_{\text{Sulphate of soda.}} + \underbrace{\mathrm{Pb\,O,\,SO_3}}_{\text{Sulphate of lead.}} + \underbrace{\mathrm{Cu_2\,I}}_{\text{Subiodide of copper.}} + \underbrace{\mathrm{I}}_{\text{Iodine.}}$$

And the second, by

$$\mathrm{I} + 2\,(\mathrm{Cu\,O,\,SO_3}) + 2\,\mathrm{Fe} = 2\,(\mathrm{Fe\,O,\,SO_3}) + \mathrm{Cu_2\,I}.$$

The proper period for arresting the addition of the cupreous salt and filings in the latter case, is when the characteristic smell of iodine disappears. No time should be lost in removing the precipitate from the ferruginous salt and filings by washing and decanting from the fragments of iron, and subsequently filtering through a cloth. Both portions of iodine are desiccated at a gentle heat, and the dry compound mixed with twice or three times its weight of peroxide of manganese, and as much strong sulphuric acid as will form it into a paste, and the mixture strongly heated in a subliming apparatus, when iodine passes off and is received in appropriate vessels: thus—

$$\underbrace{\mathrm{Cu_2\,I}}_{\text{Subiodide of copper.}} + \underbrace{2\,\mathrm{Mn\,O_2}}_{\text{Binoxide of manganese.}} + \underbrace{4\,(\mathrm{HO,\,SO_3})}_{\text{Sulphuric acid.}} =$$

$$\underbrace{2\,(\mathrm{Cu\,O\,SO_3})}_{\text{Sulphate of copper.}} + \underbrace{2\,\mathrm{Mn\,O,\,SO_3}}_{\text{Sulphate of manganese.}} + \underbrace{\mathrm{I}}_{\text{Iodine.}}$$

The use of sulphuric acid may be dispensed with in the above process, but the heat must be much more elevated when that agent is not employed. In this case, the binoxide of manganese is decomposed into sesquioxide of manganese and oxygen, which displaces the iodine combined with the copper, as shown in the annexed equation:—

$$\underbrace{Cu_2\,I}_{\text{Subiodide of copper.}} + \underbrace{4\,Mn\,O_2}_{\text{Binoxide of manganese.}} = \underbrace{2\,Mn_2\,O_3}_{\text{Sesquioxide of manganese.}} + \underbrace{2\,Cu\,O}_{\text{Oxide of copper.}} + \underbrace{I.}_{\text{Iodine.}}$$

According to SOUBEIRAN, this method is very economical, and affords as much as one per cent. of the mother-liquor operated upon.

At the Cherbourg Works the mother-waters are treated in slight excess with sulphuric acid, and the solution is afterwards boiled for some time; during this operation the sulphides, hyposulphites, and sulphites are decomposed, sulphurous acid, *et cetera*, being eliminated, and sulphur precipitated. Some time is now allowed, in order that the solution may clarify, and when this is effected, the supernatant fluid is drawn off from the precipitate and diluted till it marks 40° Twaddell, and then chlorine passed into it to saturation from a generating apparatus, such as that shown in Fig. 269. The chlorine passes off from the stills, A, B, where binoxide of manganese and hydrochloric acid are made to act upon one another, or chloride of sodium, sulphuric acid, and binoxide of manganese, and proceeds by the conduit, E, into the vat, where it liberates the iodine from its combination in the mother-liquor. The end of this operation is the decomposition of the iodide present, or rather of the hydriodic acid, and the evolution of the iodine by the substitution of the chlorine; the iodine, being only slightly soluble, precipitates. In transmitting the chlorine through the liquid, it is necessary to guard against two evils: the first arising from the use of this agent in insufficient quantity, for in this case the iodine compound remains in part undecomposed; the second, produced by an excess of the gas, owing to the formation of chloride of iodine, which passes off in vapor, and is lost. Hence, to determine the exact point, it is necessary to test a part of the liquid as well with chlorine as with a solution of iodide of potassium, to prove, on the one hand, if there remains any further portion of the salt unacted upon; and on the other, if the agent be present in excess. Should the latter be the case, a further addition of mother-liquor is made to combine with the free chlorine. When the decomposition is complete, the contents of the vessel are allowed to settle, and after a time the clear liquor containing chlorides and sulphates is drawn off from the iodine. The latter is repeatedly washed by decantation, till the washing gives no indication by the hydrometer of the presence of salts. The iodine is afterwards put and left to drain in a conical vase of pottery-ware, the bottom of which is perforated and rests upon a jar of freestone; it is then dried upon sheets of filtering-paper laid upon well-dried cinders, or upon porous tiles.

Fig. 269.

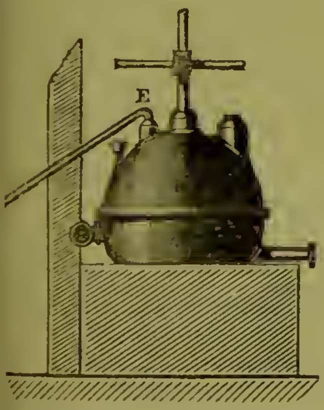
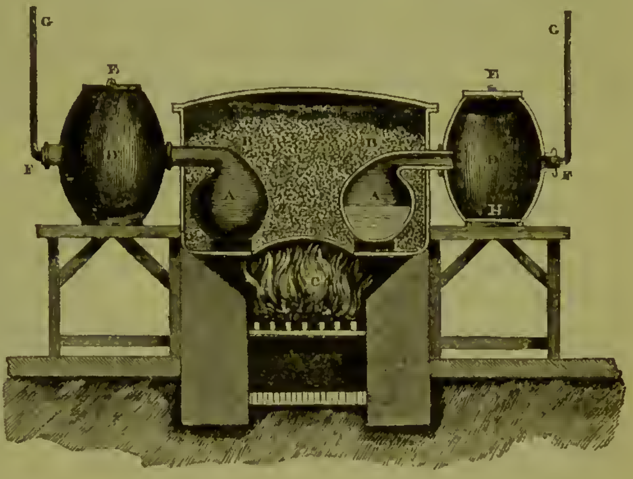


Fig. 270



The next step is the purification by a process of sublimation in an apparatus like that shown in Fig. 270. The iodine is introduced into the retorts, A A, which form a gallery of two rows, to the number of six; they are immersed in the sand of the cast-iron case, B B, which is heated by the fire, C. Into each of these about forty-five pounds of the crude iodine are introduced; they are then wholly buried in the sand, the neck as well as the body of the retort. This precaution seems necessary, to prevent the condensation of the iodine vapors in the neck, and the obstruction of the passage which would ensue. That this may be guarded against as much as possible, the necks of the retorts are short, and the receivers placed in connection with them as close to the sand-bath as possible. An elliptical cistern, D D, is used for this purpose, the beak of the retort entering at the side. It is furnished with a movable cover, E, to facilitate the removal of the iodine; it has likewise a perforated plate at the bottom, H, to allow any water which may condense to drain off. A tubulure, F, at the opposite side to that which receives the beak of the retort, allows the vapor of water to pass off by the pipe, F G, out of the range of the operation. In this way the iodine is obtained in fine large crystals.

When the bromine which is present is to be recovered, the liquor drawn off from the precipitate is evaporated to dryness, the residue compounded with sulphuric acid and binoxide of manganese, and distilled from a leaden vessel. Bromine passes over, and is received in strong sulphuric acid, in which it sinks, and is thus prevented from fuming, and injuring the health of the workmen.

IMPROVED PROCESSES.—BARRUEL'S process resembles the last in some of its operations. The remaining mother-liquor is evaporated to dryness, the residue mixed with about one-tenth of its weight of binoxide of manganese, and then heated to about incipient redness, the mixture being kept stirred all the time. The heat is continued till the sulphides and hyposulphites are thoroughly oxidised, which is known by treating a sample of the substance with sulphuric acid, and observing if sulphide of hydrogen be evolved. In this operation the heat should not be raised to such a degree as would cause the evolution of iodine, of which the characteristic violet vapor would be an indication. Water is added to the mass, and the sulphates and iodide of sodium are washed out; using only as much water, however, as will afford a solution of 36° Beaumé. Chlorine gas is now passed through the filtrate, and the iodine which is precipitated purified, as described in the preceding method.

In order to avoid the loss of iodine consequent upon the burning of the plants for the production of kelp, Dr. KEMP suggests a method whereby the iodine may be extracted, and the burning—as in the production of kelp, by which, doubtless, much iodine is dispersed—dispensed with. His suggestion is to crush the roots which contain the largest proportion of iodine, and to set them by in a heap, tank, or any convenient vessels, for a few days, and after the fermentation which ensues has subsided, to extract the soluble salts, among which will be the chief portion of the iodides, with cold water slightly acidulated with ordinary hydrochloric acid. This liquid is to be then treated with chloroxide of calcium—bleaching powder—in slight excess, so as to liberate the iodine, and the latter precipitated by adding to the liquid a sufficient quantity of amido-acetate of lead—prepared by adding a solution of tribasic acetate of lead to well-washed potato starch—by which the whole of the iodine is carried down. The precipitate may be washed and dried, and in the hands of the manufacturer the iodine may be removed from it by adding a solution of sulphide of potassium, which precipitates sulphide of lead, leaving iodide of potassium in the liquid. After filtration the liquid may be concentrated, and the iodine extracted by one or other of the processes mentioned. The fluids from which the precipitated compound of iodine and amido-acetate of lead is separated, may be useful in an agricultural point of view, either for mixing in the compost heap, or with other liquids in the manure tank. The cakes of cellular tissue which result from the pressure of the material after fermentation, may be dried and used as fuel; the ashes being preserved, on account of the portion of iodine they still retain, as well as for the other salts, which are valuable, both in an agricultural and manufacturing point of view.

Professor BECHI has indicated a process by which iodine may be economically obtained from river and other waters containing it in small proportion. His method of procedure is, to treat the waters with a mixture of one part of sulphuric acid and two of nitric, and to pass the acidulated liquor into a tank or vat, having a funnel-shaped bottom, and filled with lamp-black that has been heated to redness, or well-made ivory-black. The acids have the effect of removing the bases from the iodine, and on transmitting the solution through the charcoal, the latter is retained. When the lamp-black is charged with the iodine, and it is desired to obtain it, a solution of potassa is added, or what is better, the carbonaceous matter is mixed with hydrated protoxide of iron in a tub. After a while the iodine is taken up, and an iodide of potassium or of iron produced. When the action has been sufficiently completed, water is allowed to flow upon the mass to dissolve these salts, the solution being drained off in another funnel-shaped vessel, which is stopped in the tube part with sponge or other porous material. The liquor is evaporated to dryness; and, in case of potassa being used, the iodide and iodate are decomposed by sulphuric acid and binoxide of manganese in the manner described in the foregoing. The iodide of iron may be operated upon in the same way; or, if it be thought better to dispense with the evaporations, a sulphate of copper solution may be added, and the precipitate of subiodide of copper, which falls after filtration and washing, distilled with sulphuric acid and binoxide of manganese, *et cetera.*

In a paper by SCHÖNBEIN—see *Chemical Gazette*, vol. viii., p. 166—several substances are described which are able to decompose the alkaline iodides, so as to liberate the non-metallic element in the dry way. Such are the metallic oxides and acids, containing two, three, and five equivalents of oxygen; but many seem to exercise an unequal degree of power in effecting this change. The most remarkable are arsenious acid, chromic acid, sesquioxide of iron, and protoxide of copper; but there is danger in employing the first of these, lest a portion of the poison might be driven off by an increased temperature with the iodine, and thus render its application dangerous as a therapeutic agent. When three parts of bichromate of potassa are ground and mixed with two of iodide of potassium, and the mixture is submitted to dry distillation in a stoneware retort, the whole of the iodine is set free, leaving in the vessel a greenish mass, which is a mixture of chromate of potassa and sesquioxide of chromium. The decomposition is represented by the following equation:—

$$\underbrace{5\,(KO,\,2\,Cr\,O_3)}_{\text{Bichromate of potassa.}} + \underbrace{3\,KI}_{\text{Iodide of potassium.}} = \underbrace{8\,(KO,\,Cr\,O_3)}_{\text{Chromate of potassa.}} + \underbrace{Cr_2\,O_3}_{\text{Sesquioxide of chromium.}} + \underbrace{3\,I}_{\text{Iodine.}}$$

The iodine which is thus produced is very pure, and no loss either of it or the reagent is experienced; for the chromate, which is a residuary product of the distillation, is a valuable salt, and applicable for many purposes; whilst the green sesquioxide left after washing away the former, may be employed as a pigment in painting upon porcelain, *et cetera*; or by fusing it with an alkaline nitrate and carbonate, it may be reconverted into a bichromate of the alkali, which may be employed to decompose a fresh portion of iodide.

Iodine is also set free when anhydrous sesquichloride of iron is mixed with iodide of potassium, even at ordinary temperatures; and, on the application of heat, it passes off in dense vapors, which may be received in the usual manner. The change of the substances in this instance is due to the reduction of the ferruginous sesquisalt to that of a protosalt; the liberated equivalent of chlorine assimilating with the potassium, and thus setting the iodine free:—

$$\underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}} + \underbrace{KI}_{\text{Iodide of potassium.}} = \underbrace{2\,Fe\,Cl}_{\text{Protochloride of iron.}} + \underbrace{K\,Cl}_{\text{Chloride of potassium.}} + \underbrace{I}_{\text{Iodine.}}$$

Sesquisulphate of iron may be advantageously substituted for the preceding salt; for, when an alkaline iodide is moderately heated with it, dense vapors of iodine are liberated, quite free from sulphurous acid or other impregnation. Hence, by employing sesquioxide of iron and iodide of potassium in equivalent proportions, and adding to the mixture three equivalents of sulphuric acid, so diluted as not to be able by itself to liberate iodine, then moderately heating—the whole of the iodine passes over into the receiver, and the residuary matter is composed only of sulphates of potassa and of iron, as may be seen by the subjoined formula representing the interchange which takes place :—

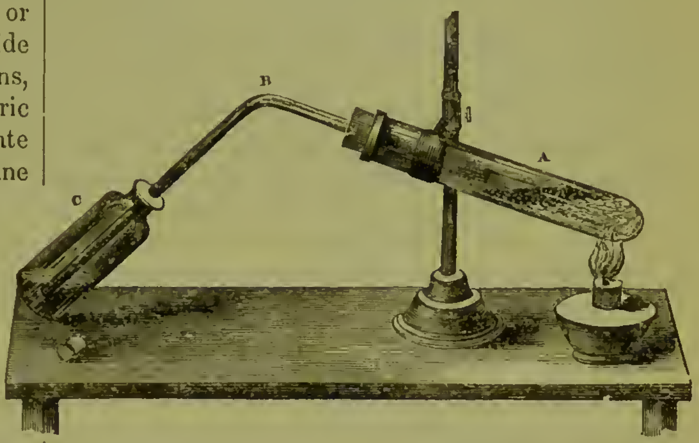
$$\underbrace{Fe_2\,O_3}_{\text{Sesquioxide of iron.}} + \underbrace{KI}_{\text{Iodide of potassium.}} + \underbrace{3\,(HO,\,SO_3)}_{\text{Sulphuric acid.}} = \underbrace{2\,(FeO,\,SO_3)}_{\text{Protosulphate of iron.}} + \underbrace{KO,\,SO_3}_{\text{Sulphate of potassa.}} + \underbrace{I}_{\text{Iodine.}}$$

COMBINATIONS OF IODINE.—Allusion has already been made to the compounds which iodine forms with some of the other elements; and a short description of the more important and useful products formed by combining this element with others, both of a metallic and non-metallic nature, will now be given.

All the non-metallic elementary bodies, with the exception of fluorine, are capable of entering into combination with iodine, either in single or multiple proportions, and many of these compounds are so persistent as to offer considerable resistance to opposing affinities before being resolved into their elements. Like chlorine, sulphur, phosphorus, *et cetera*, iodine constitutes with hydrogen and oxygen acid compounds which, in their general characteristics, are analogous in every respect. With nitrogen and ammonia it affords a compound which is eminently explosive, but with the other simple bodies its combinations offer little interest beyond the precincts of the laboratory. Many of its compounds with the metals are very valuable, as well in medicine as in many branches of industrial art; and to the chemist they are in frequent demand as effective reagents both for ascertaining the presence and estimating the proportion of numerous bodies. Of these, however, reference will be made only to those of alkali metals, iron, silver, mercury, and a few others.

IODIDE OF HYDROGEN—*Hydriodic Acid—Iodhydric Acid.*—Next to oxygen, chlorine, bromine, and fluorine, iodine manifests the greatest affinity for hydrogen; consequently, it abstracts this element from its combinations of phosphide of hydrogen, sulphide of hydrogen, ammonia, as well as from alcohol, ether, and volatile oils; in each instance hydriodic acid results. A similar metamorphosis with regard to the iodine takes place when it is mixed with water in the presence of a body capable of abstracting oxygen from the latter; and by this means hydriodic acid is sometimes prepared. Thus, when a mixture of nine parts of iodine and one of phosphorus is introduced into a tube, A—Fig. 271—and covered with moist quartz, sand, or powdered glass, and heat applied, decomposition of iodide of phosphorus, which is at first formed, takes place, as it comes in contact with the thin stratum of moisture, and hydriodic and phosphorous acid are produced; the former being volatile, may be conducted by a tube, B, to the receiver, C, in which it may be collected. The change of elements in the reaction alluded to may be expressed thus :—

Fig. 271.



$$PI_3 + 6\,HO = 3\,HO,\,PO_3 + 3\,HI.$$

Only a slight heat should be applied to produce this decomposition, for, if the temperature be elevated, some terhydride of phosphorus is apt to form and pass over into the receiver, and contaminate the hydriodic acid. Another method is to compound one part of phosphorus, fourteen of iodide of potassium, and twenty of iodine, with a little water, and submit the mixture to heat in a retort or distillatory vessel fitted up on the principle of the apparatus in the preceding figure. When the evolution in this case becomes too rapid, the retort should be cooled by plunging it in cold water; and, on the other hand, when it slackens, the heat must be reapplied.

Several modes may be adopted for preparing this acid in the liquid state: thus, iodide of barium or of lead may be decomposed by an equivalent proportion of sulphuric acid, and the liquid, after filtering off the insoluble precipitate of sulphate of baryta or of lead, concentrated; this product will be aqueous hydriodic acid. Iodine is diffused in water, and sulphide of hydrogen transmitted through it, when decomposition of the latter takes place, sulphur being precipitated, and hydriodic acid produced. A difficulty is, however, experienced in this process, notwithstanding its being effectual—namely, the evisceration of a portion of iodine by the depositing sulphur, by which the whole of the former cannot be conveniently transformed in its hydracid. DUMAS proposes to remedy this defect by merely saturating a given volume of water with iodine, and, after allowing the insoluble portion to subside, and decanting the brownish fluid, he directs that the sulphide of hydrogen should be passed through it till it becomes colorless. The deposited sulphur is then filtered, and the filtrate again charged with the iodine, and the portion which dissolves again acted upon as before. In this way the whole of the iodine may be converted into the acid; for at each succeeding saturation, in consequence of the portion of hydriodic acid that is formed, the liquid acquires the property of dissolving a larger quantity of the iodine. The process is troublesome, however, from the repeated filtrations and solutions. Hydriodic acid might be obtained with considerable facility by passing the gas through a solution of iodine in alcohol, were it not that some sulphide of carbon would be produced by the action of the sulphur on the spirit, and which could not be conveniently removed.

Hydriodic acid, prepared according to the first of these methods, is a colorless gas, soluble in water, and capable of strongly reddening litmus; it has an acerb taste and very pungent odor, somewhat similar to hydrochloric acid. When allowed to escape into the air, it produces dense white vapors, which are very suffocating when inhaled. Its density is 4·3757, according to Thomson, but Gay-Lussac gives it 4·4429, air being taken as unity; it is neither a combustible body nor a supporter of combustion. Steam, sulphurous acid, chlorine, bromine, and a few other bodies, are capable of decomposing hydriodic acid with the separation of iodine in every instance. The gas is composed of half a volume of iodine and half a volume of hydrogen. In the liquid state hydriodic acid is colorless, and of a specific gravity 1·700. It is highly acrid, and possesses an odor similar to that of the gas. Upon exposure it gradually suffers decomposition, being converted into hydriodous acid with the evolution of hydrogen; but, with prolonged contact with the air, the oxidised portion reacts upon the remainder, and causes the liberation of the iodine, which separates in fine lamellar crystals.

Sulphuric acid, when concentrated, sets free the iodine, a portion of the agent being at the same time broken up into sulphurous acid and oxygen. Hydriodic acid has been solidified by Faraday at a temperature of —59·8° Fahr. In this state it is perfectly transparent and colorless, but intersected with fissures like ice. The tension of the vapor at 0° is 2·9 atmospheres.

This acid is capable of decomposing the oxides of most of the metals affording metallic iodides and water. Its symbol is HI, and its atomic weight 127.

Iodine forms, with oxygen, compounds of various degrees of oxidation, the lowest being iodic oxide—IO, and iodous acid—IO_2; the highest iodic acid—IO_5, and periodic acid—IO_7. The latter three constitute salts with the metallic bases, which are called iodites, iodates, and hyperiodates respectively. To enter into a description of the processes by which they are prepared, would not be warranted by the uses which they serve—namely, of forming the links of analogy between iodine and chlorine, bromine, *et cetera*.

With sulphur, phosphorus, chlorine, and bromine, it produces several compounds, which are very interesting to the chemical student. The combination of iodine with nitrogen is remarkable, in being analogous to the chloride of this element, although the explosion which it produces is much less violent.

Iodide of Nitrogen.—If dry iodine and ammonia are brought together in close vessels, they form a brownish liquid, which is simply a combination of the two substances, and which may be represented by the formula $3(NH_3)I_2$. When, however, the iodine is digested with a strong solution of pure ammonia, the compound in question falls as a black powder. The same change takes place when carbonate of ammonia is substituted for the caustic alkali, or chloride of iodine for the pure element. To favor the reaction in this case, the mixture of the ingredients should be effected with a gentle abrasion in a mortar. The powder should be washed on a filter with water, to remove the excess of ammonia and the iodide of ammonium which forms. Another method for preparing the compound with equal facility, but without incurring the risk of spontaneous explosion, is to dissolve the iodine in alcohol 54·5° Twaddell, and, after decanting the tincture, saturating it with a strong solution of caustic ammonia. After briskly agitating, the mixture is diluted with water upon which the iodide of nitrogen precipitates, and may be washed in the cold with this liquid either by subsidence and decantation, or on the filter. The iodide thus produced is not spontaneously decomposed; but Serullas remarks, that if the iodine be precipitated from the alcoholic solution by water, and the solid thus recovered treated with ammonia, a compound results which is very apt to explode even during the preparation. Subsequently to the affusion, the compound is dried carefully upon bibulous paper at the ordinary temperature. In performing this operation, care should be taken to divide the mass into small portions, which ought to be placed at a distance from one another, in order to preclude the possibility of an explosion of any considerable quantities of the salt.

Millon states that it may be desiccated with safety in a bell surcharged with ammoniacal gas, and no decomposition occurs even after lengthened exposure, provided the atmosphere is one of ammonia.

The slightest cause is adequate to decompose the iodide of nitrogen with a violent explosion, and the evolution of a violet light which is visible in the dark. The feather of a quill drawn over the powder is sufficient to produce this effect, and if contained in a dish in moderate quantity, the force is such as to shatter it in pieces. Even if rubbed strongly under water, an explosion takes place; but the causes which determine this change in the air are incapable to effect the decomposition when it is mixed with large quantities of water. It is not liable to explode by mere contact with oils and fats, like the chloride of nitrogen. The products of the decomposition of this peculiar salt, so far as they have been examined, seem to be pure nitrogen, finely divided iodine, and hydriodic acid; but some assert that iodide of ammonium is produced. Marchand found that traces of the latter salt were formed upon the sides of a glass jar, in which portions of the nitrogenous compounds had been successively exploded. Water gradually dissolves the iodide of nitrogen with the formation of iodide and iodate of ammonia, free iodine, and the evolution of small quantities of nitrogen. By the action of heat, or sulphuric or nitric acid, the action is considerably expedited. Sulphide of hydrogen effects an immediate decomposition of this compound, the products being iodide of ammonium, hydriodic acid, and sulphur; the alkalies, lime, *et cetera*, operate in a similar way with the liberation of ammonia, and the formation of an alkaline iodide and iodate.

Composition of Iodide of Nitrogen.—The composition of this body is as yet somewhat doubtful, being regarded in the several lights of iodide of nitrogen—NI_3, iodide of amidogen—$NH_2\,I$, or as a mixture of the former of these with an equivalent of ammonia. The following are the data furnished by the calculations of the investigators whose names are attached :—

GAY-LUSSAC.

A

			Centesimally.
1 Eq. of Nitrogen............	14	=	3·57
3 Eqs. of Iodine..............	378	=	96·43
	392	=	100·00

B

1 Eq. of Nitrogen	14	=	10
1 Eq. of Iodine	126	=	90
	140	=	100

MILLON.

1 Eq. of Amidogen { 1 Eq. N =	14	=	986
1 Eq. of Amidogen { 2 Eqs. H =	2	=	1·41
1 Eq. of Iodine =	126	=	88·73
	142	=	100·00

According to the recent analysis of BUNSEN, however, it appears that the composition of the compound is NI_3, NH_3, but that another compound of these elements exists, presenting the composition indicated by the formula $4\,(NI_3),\ NH_3$, and which results from the precipitation of an aqueous solution of chloride of iodine by ammonia. In either case he regards these iodides as ammonia compounds, in which the hydrogen is entirely replaced by iodine, and which unite with an equivalent of undecomposed ammonia, as expressed by the formulæ. He gives the equation representing the formation of this explosive body by the mutual action of iodine and ammonia, thus—

$$\underbrace{2\,NH_3}_{\text{Ammonia.}} + \underbrace{I_6}_{\text{Iodine.}} = \underbrace{(NH_3\,NI_3)}_{\text{Explosive compound}} + \underbrace{3\,HI}_{\text{Hydriodic acid.}}$$

And by the effects of ammonia upon chloride of iodine, thus—

$$\underbrace{2\,NH_3}_{\text{Ammonia.}} + \underbrace{3\,ICl}_{\text{Chloride of iodine}} = \underbrace{(NH_3\,NI_3)}_{\text{Explosive compound.}} + \underbrace{3\,HCl}_{\text{Hydrochloric acid.}}$$

Combination of Iodine with Metals.—With most of the metals iodine enters into combination, producing metallic iodides, but, in forming such, very diverse phenomena are exhibited; some are produced instantaneously, on account of the force of the affinity which exists between the elements, whilst others require very careful and circuitous manipulations, in order to effect the union of both substances.

Only a few of these combinations have been brought into use in the arts and sciences, consequently it will be unnecessary to pursue their description beyond those compounds which are available in medicine, photography, *et cetera*. Such are the alkaline iodides, iodides of iron, of mercury, and of silver, with a few others.

Iodide of Ammonia.—When dry ammoniacal gas and iodine are brought in contact, combination takes place, and a heavy blackish-brown, very tenacious liquid is produced; the same compound is obtained on gently heating equal weights of sesquicarbonate of ammonia and iodine in a retort or porcelain tube, water and carbonic acid being formed. The change may be expressed thus—

$$\underbrace{2\,NH_4O,\ 3\,CO_2}_{\text{Sesquicarbonate of ammonia.}} + \underbrace{2\,I}_{\text{Iodine.}} = \underbrace{2\,NH_3\,I}_{\text{Iodide of ammonia.}} + \underbrace{2\,HO}_{\text{Water}} + \underbrace{3\,CO_2}_{\text{Carbonic acid.}}$$

The compound is easily decomposed in part when heated, ammonia being set free; the chief portion of the iodine salt, however, sublimes in violet-colored vapors. It indicates the presence of ammonia and iodine. Its composition, according to MILLON and BINEAU, is—

MILLON.

	At. weight		Centesimally.
1 Eq. of Ammonia, ...	17	=	11·89
1 Eq. of Iodine,.............	126	=	88·11
$NH_3\,I$,......................	143	=	100·00

BINEAU.

	At. weight		Centesimally.
3 Eqs. of Ammonia,..........	51	=	18·02
2 Eqs. of Iodine, ...	232	=	81·28
$3\,NH_3\,2\,I$..................	283	=	100·00

Iodide of Ammonium.—The compound which is met with in commerce, and intended chiefly for the photographer, is prepared by neutralizing a solution of ammonia with hydriodic acid gas, and subsequently decomposing any iodate of the alkali, by transmitting a slight excess of sulphide of hydrogen through the liquid, evaporating the liquor in a water-bath, and afterwards filtering off any deposited sulphur. When the evaporation is conducted carefully under the bell jar of an air-pump, the salt crystallizes in cubes and is colorless; but if exposed to the air, it readily deliquesces, and turns brown, owing to a portion of the iodine being set free. It may be prepared likewise by bringing ammoniacal and hydriodic acid gases in contact, or by decomposing iodide of iron by carbonate of ammonia, filtering off the ferruginous precipitate, and evaporating the solution till the iodide crystallizes.

The iodide of ammonium thus prepared is a very deliquescent salt, very soluble in water and alcohol. By keeping, even in diffused daylight when out of contact with air, it decomposes, turning brownish-yellow, ammonia being evolved. It may be represented as $NH_4\,I$, or $NH_3\,HI$, and its per centage composition as—

	At. weight.		Per cent.
1 Eq. of Ammonium,.........	18	=	12·50
1 Eq. of Iodine, ...	126	=	87·50
$NH_4\,I$,.......................	144	=	100·00

Iodide of Potassium.—This salt is one of the most valuable compounds of iodine; its importance is derived from its medicinal effects chiefly; but as a reagent in the laboratory and in photography it is, especially for the latter, in general use. There are several recipes for preparing it, the most appropriate of which will be here noticed.

When potassium and iodine, or iodine vapor, are brought together, rapid combination takes place with a considerable rise of temperature, and the evolution of a violet light. If the combination be aided by heat, the union of the two elements is often attended with a violent explosion. The result is iodide of potassium.

To prepare this body with materials which are more easily obtained, and at less expense and trouble than potassium, other processes are adopted. The simplest of these appears to be the following:—Powdered iodine is agitated with a solution of caustic potassa as long as the former dissolves. Its point of saturation is known by the liquid acquiring a brownish tint. When this happens, any excess of iodine is removed by subsidence and decantation of the liquor, or it is acted upon by a proportionate quantity of the alkaline lie. By evaporation there is obtained a white residuary mass, consisting of iodide and iodate; the latter is decomposed by heating the mass gently for some time, when iodide of potassium only remains. There is need, however, of giving particular attention to this part of the operation; for if the temperature be too elevated, some loss of iodide of potassium by volatilization is sustained; and, on the other hand, if too low, portions of iodate remain undecomposed and contaminate the salt. To avoid this, **ORFILA**, and latterly **SCANLAN**, recommend to mix the dry residue with charcoal-powder before submitting it to the action of the heat; this has the effect of bringing about a more perfect decomposition, and at a lower temperature, than could be effected without it. No iodine is liberated, and the whole of the oxygen of the iodate is taken up by the carbon, which is thereby converted into carbonic acid. After heating, the mass is exhausted with water, which dissolves out the iodide. Alcohol may be substituted with advantage when a very pure product is desired, for this takes up only the iodide and leaves the carbonate of potassa, which is nearly always present. By distillation the spirit may be removed, and the iodide crystallized from the concentrated alcoholic solution, or from water. If the residue, after the first evaporation, be treated with alcohol only, the iodide of potassium dissolves, the iodate and any carbonate which might have been present in the alkaline liquor remaining behind. This residuary salt may be afterwards heated with charcoal, and the iodide to which it is reduced extracted as above. In both cases the changes which occur may be thus symbolized:—

$$6\ KO + I_6 = 5\ KI + KO,\ IO_5;$$

the final product by the application of the heat becoming iodide of potassium, thus:—

$$KO,\ IO_5 = KI + O_6;\ \text{or,}\ KO,\ IO_5 + C_3 = KI + 3\ CO_2.$$

The method of saturating a solution of potassa, or of carbonate of potassa, with hydriodic acid, offers very good results, were it not that the preliminary operation involved in the preparation of the hydriodic acid renders the course rather circuitous. By forming an iodide of zinc, as recommended by **LE ROYER** and **DUMAS**, the operation is shortened and simplified. Zinc turnings, water, and iodine are agitated together in a close vessel, and the metallic salt which is thus produced is afterwards decomposed by addition of carbonate of potassa to the liquid as long as a precipitate appears. The carbonate of zinc is filtered, and the solution evaporated to the crystallizing point. This method is objected to on account of the difficulty which is experienced in removing the last traces of iodide of zinc. In order to obtain a pure salt by this process. **GIRAULT** gradually pours the cold solution of the iodide of zinc into a boiling hot one of carbonate of potassa as long as there is any effervescence observed; cold water is then added to the mixture, and the whole filtered, and the carbonate of zinc washed twice with water. The trace of zinc still held in solution is removed by the cautious addition of carbonate of potassa, the precipitate filtered, and the liquid concentrated and set by to crystallize. By many iron is substituted for the zinc, but the further steps in the process are decidedly the same. Two parts of iodine, one of iron, and ten of water are agitated together in a close vessel till the liquid loses its brown color; as soon as this happens, the liquid is filtered, and precipitated by a solution of caustic or of carbonate of potassa heated to the seething point. Care must be taken that the air is as much as possible excluded during the production of the iodide of iron, so as to prevent the formation of a basic iodide of this metal, which could be decomposed only by an excess of alkali.

The Dublin college directs the conversion of the iodine into hydriodic acid by sulphide of hydrogen, and the neutralization of this product either by potassa or carbonate of this alkali. **TADDIE** employs an alcoholic solution of iodine, or iodine diffused in water, and adds to it an aqueous or alcoholic solution of sulphide of potassium till the whole becomes colorless. Sulphur which separates in this operation is removed by filtration, and the liquid evaporated to obtain the salt in a crystalline state. It may be observed that in this process, when alcohol is employed, the iodide of potassium is always more or less of a brown color. Further, when the sulphide of potassium is present in excess the liquid becomes cloudy, to remove which a greater quantity of iodine must be added. Notwithstanding these precautions, it appears, that the iodide of the alkali produced is, to some extent, impregnated with sulphur; for upon heating, it turns grey, and evolves sulphide of hydrogen. The process recommended by **STEPHANI** is merely the old one of **TURNER**, mentioned above, modified. Into a bath of the caustic alkali, iodine is introduced in small portions at a time until the liquid begins to be tinged. The weight of iodine necessary to effect this is found by having a determined quantity of iodine to begin with, and weighing what remains. After the point of incipient coloration is observed, as much more iodine as is already contained in the liquid is to be added, and the whole agitated until it dissolves. Iodide of potassium and iodate of potassa are thus produced, and by treating the liquor with sulphide of sodium, prepared by saturating a solution of an equal quantity of alkali to that to which the iodine was added with sulphide of hydrogen; both liquors are mixed and left to repose, when, by mutual decomposition, the contents of the vessel become muddy in consequence of the deposition of sulphur; after a short interval this sulphur falls to the bottom, when the whole is passed through a filter, and the percolating liquid concentrated so as to obtain the salt.

Stephani states that very beautiful transparent crystals are obtained in this way, and which are quite different in this respect from the salt met with in the market.

Iodide of potassium crystallizes from its aqueous solution in the form of cubes, parallelopipeds, pyramids, or octahedrons; and, according to **Kane**, sometimes in forms belonging to the square prismatic system. The crystals are soluble in about three-fourths of their weight of water at ordinary temperatures, and in six parts of alcohol of 0·85 specific gravity. By this solution in water the temperature is reduced about 75·2°. The boiling point of the saturated solution is about 248°. The salt melts at a temperature below redness, and forms pearly crystals on cooling; if air be admitted to it whilst in a state of fusion, a portion volatilizes undecomposed. **Schindler** found, when performing the experiment in glass tubes, that the volatilization does not take place below the fusing point of the glass. Chlorine, sulphurous acid, sulphuric and nitric acids, are capable of decomposing iodide of potassium, yielding iodine in the free state; or, in the case of sulphuric acid when diluted, hydriodic acid, as noticed under the manufacture of iodine. According to **Gay-Lussac**, it may be represented by KI, being composed of—

			Centesimally.
1 Eq. of Potassium,...........	39	=	23·63
1 Eq. of Iodine,...............	126	=	76·37
1 Eq. of Iodide of potassium,...	165	=	100·00

The iodide of potassium is liable to much adulteration, as well from the nature of the processes followed in its manufacture, as from intentional additions of other bodies of less value. Those bodies, the presence of which is consequent upon the method of manufacture, are carbonate of potassa, chloride of potassium, sulphate of potassa, iodate of potassa, and, under particular circumstances, traces of a substance known as xanthate of potassa. Carbonate of potassa, derived from the imperfect neutralization of the iodide or hydriodic acid, in the first instance, may be discovered by the effervescence which succeeds the addition of hydrochloric acid to a portion of the salt, and also by its solution giving a precipitate with lime water; this impurity remains undissolved when the salt is treated with alcohol. Traces of alkaline chlorides may be derived from its being contained in the alkali taken to prepare the salt. Their presence is detected by its giving a precipitate with nitrate of silver, which is soluble in ammonia, and is reprecipitated from this solvent in the state of white chloride of silver by nitric or sulphuric acids. Sulphuric acid is detected by adding to a weak acid solution a few drops of chloride of barium. Alkaline sulphates are also left undissolved when a portion of the sample is treated with alcohol. Xanthate of potassa is produced when the iodide is prepared by the action of sulphide of potassium or of barium upon iodine dissolved in alcohol. When this body is present, the taste of the salt is like that of asafœtida; it turns greyish-brown on being heated, and evolves sulphurous acid; when the heated residue is treated with water, a substance remains undissolved which is composed chiefly of carbon, but traces of sulphates are found in the solution. Iodate of potassa is detected by adding a weak acid, by which hydriodic acid is liberated; this effected, the liberated hydracid exercises a deoxidizing effect upon the iodate, its hydrogen combining with the oxygen of the iodic acid of the latter, and setting the iodine free. Thus—

$$\mathrm{KO, IO_5} + 6\,\mathrm{HI} = \mathrm{KI} + 6\,\mathrm{HO} + \mathrm{I_6}.$$

Such disengagement of iodine is indicative of the presence, not only of an iodate, but likewise of any other of the higher oxygen acids. Exclusive of the substances mentioned, and which are never contained in greater proportion than one to two per cent., adulteration of this salt has been known and detected to the extent of seventy and eighty per cent.

Besides the process, which will be detailed at the end of this article, for the analysis and determination of iodine, as well in the commercial article as in the iodides of the metals, a simple process, applicable for the estimation of the amount of iodide in the alkaline salts, may be here mentioned. It is founded upon the behavior of the alkaline iodides with chloride of mercury, whereby an equivalent of either the potassium or sodium salt precipitates exactly an equivalent of chloride of mercury in the form of iodide. The insoluble compound thus formed is, however, redissolved by a second equivalent of the alkaline salt, in consequence of the production of a soluble double iodide of mercury and potassium. The reactions may be expressed thus:—

$$\underbrace{\mathrm{KI}}_{\text{Iodide of potassium.}} + \underbrace{\mathrm{Hg\,Cl}}_{\text{Chloride of mercury.}} = \underbrace{\mathrm{HgI}}_{\text{Iodide of mercury.}} + \underbrace{\mathrm{K\,Cl}}_{\text{Chloride of potassium.}}$$

And secondly—

$$\underbrace{\mathrm{HgI}}_{\text{Iodide of mercury.}} + \underbrace{\mathrm{KI}}_{\text{Iodide of potassium.}} = \underbrace{\mathrm{HgI, KI}}_{\text{Soluble double iodide of mercury and potassium.}}$$

To test the salt, two equivalents—330 parts—and one equivalent of chloride of mercury—135·5 parts—or any less weight of each, provided this ratio is retained, are weighed and dissolved in equal measures of water, say one thousand grains. To the solution of the iodide the mercurial liquor is to be added till a permanent precipitate appears. Should it happen that no turbidness arises, even when the whole of the latter liquor has been added, it is a proof that no adulterant exists in it; but if a precipitate should occur when only the one-half or one-fourth of the mercurial liquor has been poured in, it is evident that the iodide must be adulterated with one-half or one-fourth of some spurious matter. When iodide of sodium is to be tested in this way, it will be clear that the weight of the salt to be taken will differ from that specified for the potassium salt, in proportion as its equivalent weight is less; that is, only two hundred and ninety-eight grains are required.

Iodide of potassium is used in the laboratory as an agent for producing metallic iodides, and by the photographers largely, in preparing the silver baths wherein the plates are immersed; its chief application is in the latter art, and in medicine. Its medicinal properties are, in a great measure, similar to those of iodine itself. For further information on its physiological properties, the reader is recommended to consult the able work of the late Dr. PEREIRA.

Iodide of Sodium.—The description given for the obtaining of the preceding iodide will fully answer for the manufacture of this compound. The crystals, however, retain four equivalents of water when they form in an aqueous solution of the salt; they are larger than those of iodide of potassium, and present the appearance of oblique rhombic prisms; they melt in their water of crystallization when heated, giving the anhydrous salt; if the temperature be maintained, they dissolve in 0·6 parts of cold water. According to MITSCHERLICH, it is composed of—

				Centesimally.		
				Theory.		Mitscherlich.
1 Eq. of Iodide of sodium	=	149	=	80·21	=	80·6
4 Eqs. of Water	=	36	=	19·79	=	19·4
		182		100·00		100·0

Symbol, Na I, 4 HO.

Iodide of Iron.—This salt, as already intimated, is prepared by agitating water and iron turnings, or fine wire, and iodine together, taking the precaution to retain the presence of an excess of the metal. The iodine attacks the metal, and combines with it, forming a soluble iodide of iron. The compound, though readily prepared in the state of solution, is more difficult to obtain as a solid, owing to its tendency to decompose, yielding free iodine and a basic iodide, which is but sparingly soluble. During the concentration of the solution of iodide of iron this change occurs, unless it be guarded against by the evaporation being conducted in an iron vessel, or in contact with iron wire, which prevents the oxidation of that portion of the salt which is already formed. Carefully concentrated thus, the compound may be obtained, on cooling, in the state of a crystalline mass; but in this condition it cannot be long preserved, especially when air has contact with it, iodine being set free, as just indicated, and an oxide of iron mixed with iodide remaining. This salt is of no very great importance; it is sometimes employed in medicine, with other substances; it is also occasionally used as a photographic agent. Its symbol is Fe I, and the atomic weight, 154.

Iodide of Mercury.—Mercury is capable of forming several combinations with iodine, but that which will be noticed more particularly here, is the iodide or protiodide of the metal. If two equivalents of mercury and one of iodine are triturated together in a convenient vessel, moistening the whole with alcohol, a subiodide of mercury is obtained in the form of a greenish powder; the same compound is formed when a solution of subnitrate of mercury is precipitated with one of iodide of potassium. The resulting mass is composed according to the formula Hg_2 I.

If iodine be added to the solution of iodide of potassium, and the brownish liquid which results be mixed with a solution of subnitrate of mercury, a precipitate falls which differs in composition from the foregoing. It may also be procured by adding the iodide of potassium to an acid solution of the mercurial salt, but the former is the surer method. It forms a yellow powder, which is apt to vary in its composition, according to the conditions in which the two salts are brought together. When treated with an acid, a red salt—the iodide—deposits. According to BOULLAY, this compound is composed of four equivalents of mercury and three of iodine, and is represented by the symbol Hg_4 I_3. The most remarkable of the mercurial compounds with iodine, owing to its fine scarlet hue, is that which is thrown down when dissolved chloride of mercury—corrosive sublimate, Hg Cl—is added to iodide of potassium. If the iodide of potassium has been added only sparingly, the tinge will be duller, in consequence of a portion of chloride of mercury being carried down; on addition of a further quantity of the reagent, however, this is displaced, and the whole of the quicksilver is converted into the brilliant-colored precipitate. The operator should guard against the opposite extreme of using too great an excess of the iodide, which would have the effect of redissolving it, and producing a soluble double iodide of mercury and of potassium.

The red iodide of mercury may likewise be obtained by triturating iodine and the metal together in the ratio of their equivalents, alcohol being added. This, however, should be done with only small portions at a time, for, when large quantities are operated upon, the temperature becomes so elevated as to volatilize much of the iodine. A duller-tinted compound is produced in this way, than that which results from precipitation with iodide of potassium or hydriodic acid.

When the iodide of mercury thus prepared is heated, it fuses, and a dark yellow mass remains, which, on solidifying, retains the yellow hue. As the temperature lowers, however, the original color is regained. The composition in both cases remains unaltered, consequently the dimorphous effect must be attributed to a molecular arrangement which is produced by the increased heat. Iodide of mercury is slightly soluble in water, alcohol, and ether, but hydrochloric acid, and various alkaline salts, dissolve it completely, producing soluble double salts with it. Its composition is—

		Centesimally.
1 Eq. of Mercury, ...	100......	44·25
1 Eq. of Iodine, ...	126......	55·75
1 Eq. of Iodide of mercury, ...	226	100·00

agreeing with the formula Hg I.

Iodide of mercury might be used as a pigment. It has been stated by several French chemists, that its employment was contemplated some few years ago by English dyers and printers, for giving a bright color to cloths, but the Editor has not been able to learn anything of its application in this way.

Iodide of Silver.—This salt is easily prepared by adding to a solution of a soluble silver salt, an aqueous one of hydriodic acid, or of a soluble iodide. It forms a yellowish-white precipitate, which, when dried and heated, fuses to a reddish liquid mass, but changes to a dirty yellow.

The same salt is formed when iodine is made to act upon silver foil; or, according to M. ST. CLAIRE DEville, when concentrated hydriodic acid is poured upon the metal, hydrogen being abundantly eliminated. It is found native, as specified in the beginning of this article. Iodide of silver is soluble in an excess of the alkaline iodide to some extent, but is only sparingly dissolved by water; it is not dissolved wholly by ammonia, like the chloride of this metal. In the presence of moisture, chlorine decomposes the iodide of silver, yielding a chloride of the metal and free iodine, which may be expelled by slightly raising the temperature. This reaction does not take place at a high temperature, as ascertained by M. St. Claire Deville, but, in fact, hydriodic acid is capable of expelling hydrochloric acid from chloride of silver, and producing an iodide instead, contrary to the received opinion of the force of the affinity of these elements. He also found that on making a mixture of hydrochloric and hydriodic acids, and adding it to a solution of a soluble silver salt, only iodide of silver was produced. Chlorides of potassium and of sodium, dissolved in a small quantity of water, dissolve iodide of silver freely. Strong nitric and sulphuric acids are capable of liberating iodine from the iodide of silver, a nitrate or sulphate of the oxide of the metal being formed; this does not happen, however, when water is present, or the diluted acids are employed. Iodide of silver contains—

		Centesimally
1 Eq. of Silver, ...	108	46·15
1 Eq. of Iodine, ...	126	53·85
1 Eq. of Iodide of silver, ...	234	100·00

consequently, its formula is Ag I.

The chief use which is made of this body is in Photography, and the various other systems in use for taking impressions of objects by the influence of light. As, however, in a future article this beautiful and very interesting art will be fully discussed, the action of light upon the salt in question will not be further pursued here.

Estimation of Iodine when uncombined and in combination.—The minute proportion of this element, which has often to be sought in plants, bituminous and other shales, waters, and even in the air, has taxed the inventive powers and researches of chemists for methods, of which the accuracy might be commensurate with the evident difficulty of the task undertaken. Fortunately, iodine comports itself with a few bodies in such a characteristic way, offering indications so marked as not to be surpassed in this respect by any other substance known. These are starch, silver, and palladium; and by proper modifications in the applications of only these three bodies, the methods for the estimation of iodine, as well when free as when combined, are not exceeded by any other class, either in their accuracy or extent.

Some of these methods are of recent invention, whilst others date from the first researches made upon this element by Gay-Lussac and others. Iodine in quantitative determinations is never weighed alone, but in combination with another body, with which it is chemically united—silver or palladium. These offer the greatest security for accurate results, since they produce compounds with the iodine which are unaffected by most other substances. As a preliminary to the estimation either by silver or palladium, it is necessary to convert the iodine into hydriodic acid or into an alkaline iodide; and for this purpose a sample is weighed, and treated by any of the convenient methods already detailed for the production of hydriodic acid or iodides of the alkalies. If the iodine is mixed with potassa sparingly, and the brownish liquid treated with sulphide of hydrogen till it becomes colorless, iodide of potassium results; but in adopting this process, the last traces of the sulphide of hydrogen must be expelled, so as they may not interfere with the subsequent precipitation with nitrate of silver. A solution of the latter salt with a little nitric acid is then added as long as any precipitate is formed. By placing the beaker in a warm situation, the yellow iodide of silver falls, and the supernatant clear liquid may be decanted; the residue in the beaker may be washed either by adding water to it, agitating, and after it has subsided pouring off the clear solution, or it may be thrown upon a filter, washed thoroughly, and dried in the water-bath. The bulk of the precipitate is detached from the filter, and introduced into a porcelain crucible; the paper being burned on the lid at as low a temperature as possible, and the ashes added to the matter in the vessel. Subsequently, the whole is heated to a low red heat, and when cold, weighed. From the weight of the substance, minus that of the filter-ash, that of the iodine is calculated—234 parts of iodide of silver being equivalent to 126 parts of iodine.

In conducting this operation, it would be better to wash the precipitate by decantation, and afterwards to transfer it into the crucible, evaporating the water from the latter in the bath, and finally slightly heating over the lamp and weighing. No loss would be incurred in this by reduction of any part of the compound, as is done when a filter is employed. In either case, however, the results are very accurate. When a palladium salt is at hand, the mode introduced by Lassaigne is still better, and is now almost in every instance preferred to that just described. It is the more certain and convenient, as it offers a means of determining the iodine, even in the presence of chlorine and bromine, which the use of silver does not. The following is the method:—The liquid containing a weighed portion of the iodide under examination, or of the iodine converted into an iodide or hydriodic acid, is to be slightly acidulated with hydrochloric acid, and a solution of the protochloride of palladium added as long as a precipitate continues to form; the vessel is then placed in a warm situation for twenty-four or forty-eight hours, at the end of which time the clear liquid is passed through a filter, and the russet-black precipitate collected; it is washed with warm water, and subsequently dried till the weight remains constant, and the iodine calculated from the quantity of iodide of palladium thus found. As it is somewhat difficult and tedious to dry the precipitate when washed with water, it would be well to pour some alcohol upon the filter, after all the impurities have been first removed by the hot water, and after the spirit has passed through, to replace it with a little ether. When exposed to heat, the volatile liquid will readily escape, leaving the mass quite dry. Fresenius recommends to exsiccate the compound in vacuo over sulphuric acid. As the iodide of palladium is decomposed into iodine and metal by heat, the weight of the compound is taken after driving off all moisture by long exposure to a low temperature, or as above described; and as this is done in contact with the filter, the latter ought to be tared before collecting the salt, and after being exposed some hours to a heat of a water-bath. One hundred and seventy-nine parts of the dried salt—palladium 53 + iodine 126—contains one hundred and twenty-six of iodine. According to Rosé, the iodide after desiccation may be heated in the usual way in a platinum or porcelain crucible, and from the weight of the palladium which is left, the iodine calculated. Lassaigne found that the $\frac{1}{400,000}$th part of iodide of potassium could be determined in a liquid by this means, and the modifications, to which reference will be made presently, show that this is fully corroborated.

Upon the reaction of chloride of palladium with hydriodic acid or a soluble iodide, Kersting has founded a volumetrical method of analysis for determining this element. He prepares for the purpose a number of test liquors with pure iodide of potassium and protochloride of palladium; the iodide of potassium solution is made of such a strength as to contain one part of iodine in a thousand of the liquid. This is done by dissolving 13·1 parts of the ignited salt in ten thousand parts of distilled water.

The palladium test liquor is prepared by dissolving one part of the metal in nitrohydrochloric acid with the aid of heat, evaporating the solution to dryness in a water-bath, and adding to the residue fifty parts of concentrated hydrochloric acid and two thousand parts of water, agitating the whole, and then allowing it to rest, to part with any insoluble matter. The value of this liquid is to be ascertained by adding to a given volume of it the iodide of potassium solution in successive portions, till the whole of the metal is thrown down. If the iodide test liquor be poured from a burette holding one thousand grains of water, and divided into one hundred divisions, the amount of palladium in the volume of solution operated upon may be readily ascertained from the number of measures of the other added, since each division contains exactly 0·1 grain of iodine, which is equivalent to 0·042 of palladium, since 126 : 0·1 :: 53 : 0·042.

Having thus ascertained the quantity of materials in the two test liquors, the iodide to be examined is dissolved in water, if it admits of this treatment; a certain measure is then taken and operated upon qualitatively, as it were, in order to arrive at a knowledge of the probable quantity of iodine contained in it. For this purpose a number of measures of the palladium liquid is taken in a flask and heated in the water-bath; the measures of the liquid under examination are diluted till the ten make one hundred or a thousand grains. After the palladium solution is warmed, the other is dropped in from the burette in portions, taking care not to add too much at once, and also to shake the flask after each addition. The precipitate readily falls, and by drawing off, by means of a pipette, two portions of the liquid into two tall narrow foot-glasses, and adding to one a few drops from the burette and comparing it with the other, it will be readily ascertained whether the whole of the palladium has been thrown down. If not, a further addition is to be made to the solution in the flask, to which the portions taken out for trial-tests must be put, and the whole left for a short time in the bath, heated as before from 140° to 212°, and as soon as the solid has settled to the bottom, a similar trial-test made. It is needless to say, that as the precise point is approached, the solution of iodide of potassium must be added more sparingly, and, when gained, the two liquids ought to be tested with the iodide of potassium and with the palladium liquor, using the former in one of the test-glasses, and the latter in the other. If no indication is obtained, it is proof that the whole of the palladium has been precipitated. Should, however, an excess of the iodide be added, the operator ought to introduce a few measures of the palladium test, and proceed more carefully in the precipitation till the desired point is attained. From the number of measures of the metallic solution operated upon, it is easy to ascertain the iodine, calculating from the data given in the preceding. A second test may now be performed, employing a given number of measures of the solution containing the iodine, and adding the other test solution till there is no further separation of iodide of palladium, in order to arrive at the true amount of iodine with greater certainty.

If the iodide under examination should be insoluble in water, or not well adapted for immediate solution, on account of admixture with foreign substances, it must be distilled from a small retort, with the neck turned upwards, with sulphuric acid, using for this purpose about twenty measures of the burette of strong acid, free from iodine, and from twenty to a hundred measures of water. The distillation must be continued till fumes of hydrated sulphuric acid begin to be evolved. Should the distillate contain free iodine and hydriodic acid, a few drops of starch paste, prepared by boiling one part of starch with one-tenth part of strong sulphuric acid in twenty-four of water, and then sulphurous acid, till the blue coloration occasioned by the free iodine and starch disappears, or is on the point of disappearing: on the other hand, if the substance distilled with the acid contains organic matter, causing, during the operation, an evolution of sulphurous acid, which condenses in the receiver, a few drops of the paste must be introduced, and then a solution of bleaching powder, till a faint bluish tinge begins to appear. This is an indication that the whole of the sulphurous acid has been converted into sulphuric acid; it is necessary, however, to destroy the azure tinge in the liquor by a few drops of solution of the sulphurous acid. After this, the testing with the palladium liquor is proceeded with in the manner detailed.

According to Kersting, dilute hydrochloric, sulphuric, nitric, phosphoric, and acetic acids, and also the neutral salts of those acids with the alkalies, have no influence upon this method; neither have chloride of calcium or of zinc, acetate of lead, sugar, uric acid, and the distillate of urine with sulphuric acid, alcohol, ether, starch paste, oil of lemons, and bromide of sodium, in the presence of acetic acid. The test is interfered with, however, by the presence of alkaline bromides with free mineral acids, especially upon heating; free alkalies, free chlorine, bromine, iodine, and cyanogen; large quantities of nitric acid at a high temperature, and sulphurous acid; for all these bodies prevent the precipitation of the iodide of palladium.

KERSTING has devised another mode, which is in application less complex than the foregoing, and affords, when none of those substances which interfere with the reaction are present, very trustworthy results. It is founded upon the behavior of chloride of mercury with a metallic iodide, tinged blue by the addition of a little starch paste and bromine water, in which case coloration is perceived as long as any of the iodide remains undecomposed by the mercurial salt, but by the decomposition of the last traces the blueness disappears. A test liquor, containing a certain known weight of chloride of mercury in a given volume of it, is prepared as in the preceding case, and the iodide to be examined is dissolved, and the liquor so diluted that it will contain about one part of iodine in a thousand, being previously blued by a little bromine water and starch paste, as previously mentioned. By adding the test liquor to this solution, iodide of mercury and chloride of the metal, in combination with the iodide, will be formed; but in consequence of the solutions being so diluted, the mercurial iodide dissolves, and so does not prevent the observation of the blue shade. When this disappears, the number of measures of test liquor required are read off, and from them the iodine is calculated. 135·5 parts of chloride of mercury are equivalent to 126 of iodine, and so in this proportion will any weight of the former salt in the solution added to destroy the color, be to its equivalent of iodine. When chlorides and bromides are present, also free mineral acids, acetic acid, and the acetates, the results afforded by this method are not exact.

Dr. FREDERICK PENNY has published a process for testing the quantity of iodine in iodides, volumetrically, by means of bichromate of potassa, which gives rise to the annexed reaction:—

$$\underbrace{3\,K\,I}_{\text{Iodide of potassium.}} + \underbrace{K\,O, 2\,Cr\,O_3}_{\text{Bichromate of potassa.}} + \underbrace{7\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{4\,K\,Cl}_{\text{Chloride of potassium.}}$$
$$+ \underbrace{Cr_2\,Cl_3}_{\text{Sesquichloride of chromium.}} + \underbrace{7\,HO}_{\text{Water.}} + \underbrace{I_3}_{\text{Iodine.}}$$

When heat is not applied, this is the only reaction which takes place, and by it three equivalents of iodine are set free by one of the bichromate of potassa. The manipulations are as follow:—Ten grains of pure bichromate of potassa are dissolved in about seventy measures of the burette, holding one thousand grains of water up to zero on the divided scale, and the remainder up to 0, filled with strong cold hydrochloric acid. The liquor is agitated and set aside. A weighed quantity of the salt to be examined is taken and dissolved in like manner in about a thousand grains of water, and to this the liquor from the burette is added cautiously till the whole of the iodine is precipitated. This is ascertained by letting a drop from the end of the glass-stirrer fall upon another of a freshly-prepared solution of protochloride of iron, mixed with sulphocyanide of potassium, and observing if a red coloration be produced. The bichromate solution is carefully added, stirring after each addition till this result is arrived at, and then the number of measures read off. Knowing that every ten divisions of the test solution contains one grain of the bichromate, and that their quantity effects the liberation of 2·437 grains of iodine from the sample, it is easy to estimate the weight of iodine in the quantity operated upon by the proportion:

$$10 : 2{\cdot}437 :: x : y\text{—the iodine.}$$

Before leaving this part of the subject, which must be interesting to every chemical student, it may be well to lay BUNSEN'S volumetrical method before the reader. It is founded on the behavior of sulphurous acid with iodine, which, in the presence of water, converts the iodine into hydriodic acid:—

$$\underbrace{I}_{\text{Iodine.}} + \underbrace{HO}_{\text{Water.}} + \underbrace{S\,O_2}_{\text{Sulphurous acid}} = \underbrace{S\,O_3}_{\text{Sulphuric acid.}} + \underbrace{H\,I}_{\text{Hydriodic acid.}}$$

This reaction is one among the many that the chemist and manufacturer encounter, and which at first sight appears inconsistent, since the converse can be effected as freely, namely:—

$$\underbrace{S\,O_3}_{\text{Sulphuric acid.}} + \underbrace{H\,I}_{\text{Hydriodic acid.}} = \underbrace{I}_{\text{Iodine.}} + \underbrace{S\,O_2}_{\text{Sulphurous acid.}} + \underbrace{HO}_{\text{Water.}}$$

The state in which the substances are presented to one another has a great influence upon the nature of the change, and, consequently, demands careful study. In this case, the one or other of these reactions which result, is dependent upon the state of concentration of the materials which are taken to produce the effect. By careful experiments, BUNSEN found that the first reaction only is produced when a solution of sulphurous acid, containing 0·04 to 0·05 of real acid, is brought into contact with iodine; hence, when this condition is supplied, one equivalent of sulphurous acid is converted into sulphuric acid by an equivalent of iodine.

This comportment suggests, that when an unknown quantity of iodine is mixed with an excess of sulphurous acid of the above strength, by testing how much of the reagent remains in excess after the former substance has disappeared, the difference will afford data for calculating the quantity of iodine present. By means of a solution containing a known amount of iodine, the latter part of the reaction is performed.

Standard solutions of sulphurous acid, of the forementioned strength, also one of iodine, one of iodide of potassium, and some starch paste, are required for performing the analysis by this method. The iodine test liquor is prepared by dissolving five grammes of the purest iodine in a concentrated solution of pure iodide of potassium, in a flask holding twenty thousand grains measure—twenty measures of burette—up to a certain mark, and diluting the liquor with distilled water till this mark is reached. A perfect homogeneousness of the liquid should be effected by agitation, and care taken that it does not show any brown tinge. As each hundred divisions of the burette of this liquid contains 0·25—2000 : 5 : : 100 : 0·25—it is evident that each division will contain a quantity of iodine equal to ·0025 of a gramme. Lest impurities might be contained in it, it is necessary to subject it to a corroborative test to be certain of its value.

A sulphurous acid test liquor is prepared by saturating distilled water with sulphurous acid at the common temperature; this liquid should be kept in well-stoppered bottles inverted in water. From seventy to eighty divisions of this saturated liquor should be added to every hundred burette measures of distilled water.

The iodide of potassium test liquor is prepared by dissolving one part of pure iodide of potassium in ten parts water; it should form a colorless liquid, and give no tinge even on the addition of hydrochloric acid.

It is necessary to prepare the starch paste fresh for each testing. Before proceeding to operate upon samples of unknown composition, it is requisite to find the relative proportion between the iodine and sulphurous acid solutions; and also what quantity of the respective agents is present in a given volume of them. To effect this, it is required, in the first instance, to measure off two burette measures, that is, two hundred burette divisions of the diluted sulphurous acid solution, and add thereto six or eight divisions of starch paste; then a solution of the iodine is dropped in from the burette, and the flask agitated till there is a slight excess of the iodine, and the starch acquires in consequence a persistent blue color.

Operating in this way, and supposing that, to convert the two hundred divisions of sulphurous acid into sulphuric, one hundred and eight of the iodine liquor were required, it is evident that these numbers will stand in the same relation to one another when the iodine is to be determined, as when it is wished to estimate the sulphurous acid. The next step is to find how much pure iodine is contained in each degree or burette division of the iodine test solution, and likewise its effect upon the sulphurous acid. This is done by weighing off 0·40 gramme of dry and pure bichromate of potassa, and treating it in a small retort with concentrated hydrochloric acid, and conducting the evolved chlorine into a solution of iodide of potassium. For this end the bichromate and acid are put into a flask, to which a tubulure and tube are adapted, and secured by passing a tube of caoutchouc over the neck, cork, and portion of the tube; a small glass bulb, with its long neck closed by the blowpipe, is put into the end of the eduction tube, and then introduced into an inverted retort, containing the solution of iodide of potassium. Heat is applied by means of a lamp, and, after a few minutes' ebullition of the contents of the flask, the whole of the chlorine will have passed over. There will be liberated from the iodide of potassium, by the chlorine evolved from the quantity of bichromate operated upon, 1·024 of iodine—that is, an amount proportionate to three equivalents of iodine for one of the former salt, as stated at page 400. To the solution containing the mixture of iodine and iodide of potassium, the diluted sulphurous acid liquid must be added from the burette till the brown color of the fluid has completely disappeared, and the quantity is noted, which, for example's sake, may be taken at sixteen hundred divisions. It is needless to say that there has been an excess of the acid employed on this occasion, and which is to be determined in the next operation, by introducing a little starch paste, and as much of the standard iodine solution as is requisite to communicate a blue color to the fluid. If for this purpose twenty divisions of the burette are taken, from the following calculation, founded upon the preceding tests, the value of the solution as to the iodine it contains, and the sulphurous acid it changes into sulphuric, is arrived at. As by the previous experiment it was found that fifty-four divisions of the iodised solution were necessary to oxidise two hundred of the sulphurous acid liquor, it follows that four hundred and thirty-two of the former will be required to oxidise the one thousand six hundred measures taken of the latter; but, as the experiment shows that the iodine liberated from the iodide of potassium is equivalent to this volume of test liquor, minus the twenty divisions required for the excess—that is, 432 — 20 = 412 divisions, corresponding to 1·024 of iodine—it is evident that each burette division of the iodised test liquor contains ·00248 of a gramme of iodine. Of course, each degree of the entire quantity of the test liquor possesses this value.

To test the iodine in a sample submitted, a portion is to be weighed off in a flask, and dissolved in iodide of potassium of the strength specified in the foregoing, using about ten divisions of the burette for each one-tenth of a gramme of the iodine. The dilute sulphurous acid liquor must now be added in measured quantities from the burette, till all color in the solution disappears; the quantity thus used is noted; a few divisions of starch paste are stirred with the menstruum, and the iodine test liquor carefully dropped in, stirring well after each addition till the blue iodide of starch appears. The volume of sulphurous acid and the number of divisions of the iodised test liquor which are required to oxidise the excess of the acid above what was necessary to convert the iodine in the sample to hydriodic acid being known, it is easy to find, by the following mode of calculation, the proportion of iodine in the sample. Thus, supposing that a thousand divisions of the acid solution were taken in the first instance, and that to oxidise the excess which remained of this, ten divisions of the iodine liquor were required, it follows that the weight of the sample taken, supposing it a gramme, contained 0·6448 of iodine, and, consequently, 64·48 per cent.; for, as found by the foregoing experiments, fifty-four divisions of the iodine liquor were equivalent to the oxidation of two hundred of the sulphurous one; hence 200 : 54 :: 1000 : 270, and 270 — 10 = 260 × ·00248—the amount of iodine in each division—gives 0·6448, as stated.

For the detection of the grosser adulterations of iodine, which are mentioned as being practised, although they have not come within the range of the Editor's experience—such as plumbago, sulphide of antimony, and the like—a rough estimate may be formed of the amount, by heating a weighed sample of iodine in a porcelain crucible to redness, till the whole of this element is volatilized, and weighing the fixed residue. This, though not so precise as those other methods which have been detailed, does not require that accuracy of manipulation which is presupposed to be possessed in the other instances.

When small quantities of iodine have to be found—as, for instance, in the ashes of plants, the residuary matter left after the evaporation of spring or river waters, and the like—the methods by which they are to be detected must evidently insure all possible accuracy, if the investigator is anxious to arrive at the truth. For a long time the tests known, such as decomposition of the iodide by sulphuric acid, and addition of starch paste, were found insufficient to determine the minute traces of iodine which, as appears by late researches, are contained in several bodies. Without entering upon the general description of all the tests proposed, a few of the more remarkable may be briefly noticed.

At the head of investigations of this kind stands the test of PRICE, detailed in the Transactions of the Chemical Society for 1851. It consists in operating upon the solution which is supposed to contain the iodide with hydrochloric acid and starch paste, and then adding a few drops of a solution of nitrite of potassa, when a blue coloration from the iodide of starch makes its appearance. The hydrochloric acid liberates the iodine from its basic combination, and is retained in the liquid in the form of hydriodic acid; this body is decomposed by the nitrite, the acid of which is set free by the excess of hydrochloric acid—the hydrogen being converted to water, and the iodine liberated. When much iodide is present, the color of the liquid is dark blue, and appears immediately; but when only a small quantity is contained in the substance operated upon, the shade is lighter, and a few seconds elapse before its appearance. This chemist states that he has detected iodine in a solution containing not more than the four-millionth part of it, and that there is no difficulty in ascertaining the presence of iodine in cod-liver oil, and in the mother-liquor from a few pounds of sea-water, by its aid.

M. GRANGE'S method is analogous to that just described, only that he directs the transmission of a few bubbles of fuming hyponitric acid through the solution to be tested, and already impregnated with starch paste; the reaction is instantaneous; and when the iodine forms about the five-millionth part of the fluid, a pale rose color, inclining to violet, is produced. With a larger proportion, say the one three hundred thousandth, this chemist asserts that the characteristic blue appeared; but when only the one-millionth of iodine is present, he states that no satisfactory results can be attained by this test *per se*. Coupling it, however, with another method published by RABOURDIN, founded upon the property of chloroform, of dissolving iodine, and becoming reddish-coloured thereby, it can be rendered so accurate as to satisfy the minutest inquiry. Should a portion of the fluid afford no indication with starch paste and hyponitric acid, the latter is to be transmitted through the bulk of the solution at hand, till it manifests an acid reaction; a small quantity of chloroform is agitated with it, and then drawn off with a pipette; the reddish color is removed by the addition of a little potassa, and the aqueous solution then decanted. The hyponitric test is then applied, when it does not fail to produce the characteristic blue color. In this way, the one-five millionth of iodine is easily detected. GRANGE found that bromides do not interfere with the accuracy of these reactions, for they are not decomposed by the hyponitric acid.

M. MORIDE has proposed a substitute for the chloroform in the preceding method, which offers advantages in giving a solution which is more highly colored than the chloroform becomes under similar circumstances. According to this chemist, wherever iodine is indicated by starch paste, it may be proved also by the employment of benzine more satisfactorily. This agent is rendered more valuable from the fact, that the water which is present, or which may be used to wash it, carries away any bromine or chlorine, thus leaving the iodine isolated.

Chlorine, though capable of setting iodine free from its combinations in aqueous solutions, is now rarely employed to detect iodine, since an excess of the agent converts the iodine into a colorless combination of chloride of this element. Bromine comports itself differently, for although it is capable of liberating it, still none of the iodine is redissolved. DE LUCCA has made this behavior the basis of a method for the analysis of iodides by means of a standard solution of bromide, coupled with the use of sulphide of carbon, which takes up the iodine as it is liberated by the bromine liquor. From the volume of the latter which is expended in setting free the whole of the iodine—ascertained by the sulphide of carbon being colorless when drawn off with the pipette—its quantity is found.

To show that iodine is contained in the air, *et cetera*, modifications of the processes above described have been successfully employed by CHATIN, HERAPATH, and others; but to enter into further details upon this subject, although highly interesting, appears unnecessary.

IRON.—*Fer*, French; *Eisen*, German; *Ferrum*, Latin.—Iron is a metal of a bluish-grey color, but acquiring a brilliant surface by polishing; its fracture is fibrous, and it is the hardest and toughest of all the ductile metals; it cannot be hammered into very thin plates, but may be rolled into thin sheets, and drawn into very fine wire.

The iron of commerce is seldom or never pure, containing small portions of carbon, sulphur, silicium, phosphorus, arsenic, *et cetera;* its density varies a little according to its purity and the mode of its manufacture. Purified by fusion with smithy scales, it gave in some experiments a specific gravity of 7·8439, which is increased by rolling and drawing into wire. Pure soft bar-iron, containing only a trace of carbon, has a density of 7·79; that of ordinary bar-iron is 7·788.

When iron is subjected to a red heat, it softens and becomes tough, a circumstance which adds much to its value in the manufacturing arts; and its property of welding at a white heat, gives a facility in working it which no other metal possesses. When heated above the welding point, it crumbles under the strokes of the hammer.

The melting point of iron has been variously given as 1550° C.—*Pouillet;* 1587°—*Daniell;* 6346° C. or 175° Wedgwood—*Morveau;* 158° Wedgwood—*Mackenzie.* Any impurity in the metal makes it more easily fused, and might account for small discrepancies in the melting point; but the remarkable differences shown in the above results enable us to appreciate the great difficulty of obtaining accurate measurements of very high temperatures.

Iron is attracted by the magnet, and is itself easily rendered magnetic, but does not retain this property except when converted into steel.

HISTORICAL NOTICE.—Iron, wherever known, has universally taken the lead amongst the metals in point of usefulness, and its possession by any people has invariably proved the means of advancing them in the arts of civilized life, and of raising them in the scale of nations. It is strange that, notwithstanding the difficulties in its manufacture, iron is amongst the first metals mentioned in history. MOSES tells us that TUBALCAIN, the great-grandson of CAIN, ADAM'S son, was an instructor of every artificer in brass and iron, that iron furnaces were in use in ancient Egypt, and that the hills of Palestine produced ferruginous ores. JOB says,—Iron is taken out of the earth;—and throughout the whole sacred volume this metal is referred to as being in common use, both for weapons of war and manufacturing instruments.

HOMER mentions a mass of iron as one of the prizes at the funeral games given by ACHILLES in honor of PATROCLUS, a circumstance showing the great value attached to it in ancient times, when it was so much less common than at the present day:—

> Then hurl'd the hero, thundering on the ground,
> A mass of iron—an enormous round—
> Whose weight and size the circling Greeks admire,
> Rude from the furnace, and but shaped by fire.
> * * * * *
> Who furthest hurls it takes it as his prize.
> If he be one enriched with large domain
> Of downs for flocks, and arable for grain,
> Small stock of iron needs that man provide;
> His hinds and swains whole years shall be supplied
> From hence; nor ask the neighboring city's aid
> For ploughshares, wheels, and all the rural trade.

There are also notices in HOMER and HESIOD of the methods of reducing and forging iron; but cast-iron was then unknown, an imperfectly malleable iron being produced at once from the ores in the furnace. It is conjectured that the Greeks obtained most of their iron through the Phœnicians, from the shores of the Black Sea and of Laconia. DIODORUS SICULUS refers to the Island of Elba as yielding ores of iron, which the natives were accustomed to dig and cut out of the ground, subsequently melting the mass to obtain the metal. PLINY in his Natural History enters at great length upon the manufacture of iron; he says the ores are to be found almost in every country, and that they are easily discovered by the color of the earth which breedeth the iron, and that they are tried by fire like other veins of metal. He speaks of it also as being applied to all the uses for which it is commonly employed in the present day. It is remarkable, however, that although in all the Latin writers, *ferrum*, iron, is the most common name for a sword, the weapons and cutting instruments discovered in the ruins of Pompeii and Herculaneum are almost invariably found to be made of bronze.

The furnaces which were first employed for smelting iron were probably simple conical structures, with small openings below for the admission of air, and a large opening above for the escape of the products of combustion, erected on high grounds that the wind might assist combustion. Similar rude furnaces, known as *air-bloomeries*, are still used in some countries at the present day. Successive layers of ore and charcoal being placed over the fire, the heat would be regulated by opening and closing the apertures. Subsequently, an artificial blast would be introduced, and the advantages of this appear to have been known at a very early period; for HOMER represents HEPHÆSTUS as throwing the materials from which the shield of ACHILLES was to be forged, into a furnace urged by twenty pair of bellows. This blast-bloomery would ultimately be developed into the *catalan forge*, in which malleable iron is produced directly from the ore by heating it in contact with carbon—a process still adopted in some places where wood is abundant for making charcoal, as in the Pyrenees, in Corsica, and some parts of Spain. Finally, it assumed the form of the *blast-furnace*, now in general use, and which, by completely fusing the ore in contact with the fuel, results in producing cast-iron—a compound of the pure metal with carbon.

The transformation of the blast-bloomery into the blast-furnace is supposed to have taken place in the early part of the sixteenth century; for proof exists that in the seventeenth the art of casting had arrived at considerable perfection. The more efficient operation of the blast-furnace allowed the reduction of the heaps of scoriæ, which had been gradually accumulating during the period that the blast-bloomeries had been in operation. In the Forest of Dean in Monmouthshire, in Yorkshire, and other counties, these were found in immense beds, among which were discovered Roman coins and other specimens, inscribed to the god who presided over iron. There is ample evidence of the industry of the Romans in working the iron mines of Britain, until their final abandonment of the island about A.D. 409. It is supposed, also, that the Danes, during their occupation of England, carried on the smelting of iron extensively, and hence many of the heaps above-mentioned are called in certain localities *Danes' cinders*. A portion, only, of the ore was reduced by the imperfect methods of smelting then known; and, in the Dean Forest alone, it is computed that twenty furnaces, for a period of nearly two hundred years, were supplied chiefly with the bloomery cinders as a substitute for iron ore.

Up to the beginning of the seventeenth century, charcoal was the only material employed in smelting operations. An enterprising ironmaster in Worcestershire, named DUDLEY, was the first who attempted the operation with pit-coal, and the trial was so successful, that about the year 1620 he applied for a patent for his invention, which was granted for thirty-one years. For some time he succeeded in producing considerable supplies of iron, which could be sold with good profit at a much reduced price; but this very success was the cause of his ruin, by exciting the animosity of his rivals, from whom he encountered incessant opposition, and, by combinations among masters and men, he was ultimately turned out of his works. With DUDLEY died for a time the art of making iron with pit-coal; but the rapid destruction of the forests, not only to supply the great consumption of the blast furnaces, but also the wants of a constantly increasing population, induced at length special enactments prohibiting the cutting down of timber for the use of the ironworks. The first effect of this prohibition was greatly to reduce the number of furnaces; so much so, that in 1740 the annual production, which had previously amounted to one hundred and eighty thousand tons, was diminished to seventeen thousand three hundred and fifty tons.

The change from charcoal to coke as fuel necessitated a more powerful blast, and a longer subjection of the materials to the heat. The latter was effected by an enlargement of the height of the furnace, and the former by the introduction of large cylinders, with closely fitting pistons, instead of the common forge-bellows. The earliest blowing cylinders of any magnitude are supposed to have been those erected by Smeaton at the Carron Ironworks in 1760. These improvements speedily effected an astonishing increase in the production of iron. About the year 1780, the furnaces still worked with charcoal produced only eleven tons of iron weekly, while those in which coke and coal were used averaged a weekly product of seventeen and a half tons. Dr. Ure gives the quantity of cast-iron produced in 1788 as follows:—

	Tons.
By means of coal,	48,800
By means of charcoal,	13,100
Constituting a total quantity,	61,900

In 1796 the wood-charcoal process was all but entirely given up, and the gross produce of one hundred and twenty-one blast furnaces was one hundred and twenty-four thousand eight hundred and seventy-nine tons, being near to twenty tons weekly for each furnace; and in ten years after this, 1806, there were two hundred and twenty-seven blast furnaces in this country, one hundred and fifty-nine of which were in active blast at once, and produced two hundred and fifty thousand tons of iron.

The blast furnaces were distributed as follows:—

In the principality of Wales,	52
In Staffordshire,	42
In Shropshire,	42
In Derbyshire,	17
In Yorkshire,	28
In the counties of Gloucester, Monmouth, Leicester, Lancaster, Cumberland, and Northumberland,	18
Scotland,	28
	227

Nearly simultaneous with the earliest improvements in the manufacture of cast-iron by means of pit-coal, were others of an equally important kind for converting the cast-iron into malleable or bar-iron. Hitherto this had been effected by means of wood charcoal in what are termed refiners, as is still practised in the South of France; but owing to the scarcity of wood fuel in this country, the charcoal was mixed up with coke for the refining operation; the iron produced from this was hard and of an inferior quality, and much time was required for the conversion of a ton of cast into malleable iron. England was therefore greatly indebted to Sweden and Russia for iron of good quality, and not less than seventy thousand tons annually were imported from these countries. In 1783, Mr. Richard Cort, after many trials, succeeded in converting cast-iron into malleable iron, by the use of pit-coal in a reverberatory, instead of a blast furnace, and thus introduced what is known as the *puddling process*. For some time much difficulty was experienced in puddling, from the loss of iron, and irregularity in the quality of the metal produced and the fuel used. To avoid this, the iron was subjected for a short period to a process of refining with the blast and coke fuel, previous to being transferred to the puddling operations in the reverberatory furnace. The original puddling furnace, patented by Mr. Cort in 1784, says Mushet, is now, *without the intervention of the refining*, producing tens of thousands of railway bars all over the world. This invention placed England in an independent position as respects iron, and so facilitated the manufacture of malleable metal, that before many years one work could turn out annually as much bar-iron as was made previously by the whole iron trade of the kingdom. Notwithstanding the value of these improvements, Mr. Cort did not benefit by his inventions. After spending thousands in experimenting, and giving to the world his results, those who were the gainers repudiated his claims while they adopted his processes, leaving him to drag out the rest of his days in poverty; and it was only in the course of last year that the Government granted a small acknowledgment of fifty pounds per year to the widow of the great benefactor of his country, while the children and grandchildren have been appealing to the sympathy and charity of the ironmasters, for what they should have received through their father as a right.

The general introduction of the steam-engine, as improved by Watt, contributed also to initiate a new era in the history of the iron trade, as in almost every branch of industry. Its application to pumping enabled the mines to be sunk to a greater depth, and accelerated the process of raising the coal and ores; by employing it as the motive power for urging the blast, refractory ores were reduced with facility, and the processes of rolling, forging, *et cetera*, were now effected with a rapidity previously unknown.

Lastly, the discovery of the hot-blast process, for which a patent was taken by Mr. Neilson of Glasgow in 1824, and by which three or four times the quantity of iron can be produced with little more than one-third of the fuel that was required with the cold-blast, effected another complete revolution in the iron trade, and may be regarded as marking the last era in the history of this all-important metal. The high expectations at first formed from Bessemer's new and remarkable refining process, of which an account will be given, have not yet been realized.

Sources.—In admirable harmony with the universal application and innumerable uses of iron, is its almost universal presence in nature. It is by far the most widely diffused of all the metals; there being few substances in the material world that do not contain it in greater or less amount; and yet the variety of ores from which the metal is manufactured is very limited.

Native Iron.—For a long time native iron was unknown, and its existence in nature questioned; it has been found, however, in several localities both on the Continent of Europe and in America. In this country it has been met with in minute quantity in trap rocks, but on all occasions it is found only in small portions, and is considered more in the light of a chemical or mineralogical curiosity than as a useful source of the metal. Native iron is almost pure white, more resembling silver than ordinary iron, is generally softer and less dense, and, unlike meteoric iron, contains no nickel. A mass was found with magnetite at Grass Ramsdorf, not far from Saalfield in Thuringia, which, according to KLAPROTH, consisted of:—

	Centesimally.
Iron,	92·5
Lead,	6·0
Copper,	1·5
	100·0

It is said, however, to be found in considerable quantity in Liberia. The natives use it for instruments; it is soft and flexible, and can be easily cut with a chisel. An analysis of this gave:—

Iron,	98·87	98·40
Silica,	1·63	1·60
	100·00	100·00

This is the purest yet described from any locality. In 1786, a mass of native iron, weighing upwards of thirteen tons, was found in South America, a sample of which was sent to the British Museum. It is described as being soft and compact, although the internal part of the mass is full of cavities; it had every appearance of having been in a fused state, and was considered the product of a volcanic irruption. No analysis of this sample has been made.

Small quantities of native iron have been obtained in the immediate vicinity of a coal seam which had been spontaneously ignited, and was doubtless the result of reduction by the coal; samples of this sort are excessively hard and fine-grained, and give a fracture resembling cast-steel, from which circumstance it has been named *native steel* or *steely iron.* A mass of this mineral, weighing sixteen pounds six ounces, was discovered some years since near Nexy, in the department of the Allier.

Meteoric Iron.—Large masses of metallic iron have been discovered from time to time, in different parts of the globe, embedded in the soil and also lying upon the surface; others of a similar kind have been known to fall from the atmosphere, and are hence termed meteorites. These masses are generally covered over with a kind of black enamel, which protects the metal from the action of the atmosphere. The iron forms usually a sort of network round a crystallized metallic mineral of a complicated composition. These meteoric masses are sometimes so large, and the metal which they contain so pure, as to furnish the inhabitants of the neighborhood with ample material for knives and spearheads. When examined chemically, there seems a considerable similarity in the composition of different specimens, although some of them contain ingredients which others do not. In the following table this similarity is very apparent, although the samples were obtained from localities widely apart:—

No.	Iron.	Nickel.	Cobalt.	Copper and tin.	Manganese.	Phosphorus.
1	92·47	5·67	0·23	—	—	—
2	93·77	3·81	0·21	—	—	—
3	88·04	10·73	0·45	0·66	0·13	—
4	88·23	8·52	0·76	—	—	—
5	66·56	24·70	—	—	—	—
6	83·57	12·66	—	—	—	—
7	89·78	8·88	6·67	—	—	—
8	85·61	12·27	0·89	—	—	—
9	90·88	8·45	0·66	—	—	—
10	88·98	10·35	—	0·56	—	0·11
11	85·00	13·01	1·42	0·57	—	—
12	86·64	13·04	—	0·27	—	[illegible]

These are but a few of many analyses that have been given, all showing a remarkable sameness in composition. Besides these ingredients, the meteoric mass is sometimes found to contain silica, alumina, lime, potassa, chromium, magnesia, soda, arsenic, carbon, sulphur, chlorine, *et cetera.*

Protoxide of Iron.—This oxide has never been found in nature except in combination with other matters forming distinct minerals. Its great tendency to combine with more oxygen, obtained either from the air or other substances, prevents it existing as protoxide for any length of time, unless it is entirely excluded from the presence of oxygen. This compound may be prepared by precipitating a solution of protosulphate of iron, by a caustic alkali, and carefully filtering; but it is impossible to obtain it in the dry state by this method, from its affinity for oxygen. It may be said that protoxide of iron does not exist in a separate state in nature; its composition is—

		Centesimally.
Oxygen,	8	22·86
Iron,	27	77·14
	35	100·00

Magnetic Oxide of Iron.—When the protoxide combines with more oxygen, it does not pass at once into the highest state of oxidation, but into a mixture of protoxide and sesquioxide, which is permanent and magnetic, and is hence termed magnetic oxide. This compound, when found as a mineral, has a black color, and is hard. It exists abundantly in nature in different rocks; in granite, mica-slate, clay-slate, syenite, hornblende, chlorite, and also in some of the limestone formations. Much of it is found in the Island of Elba, and it has been obtained from that island for making iron from the earliest times. It also abounds in the United States of America; and mostly all the Swedish iron is manufactured from the magnetic oxide. This ore occurs in crystallines, of which the primitive is a cube: its general forms are the octahedron and dodecahedron. Its density varies from 5·00 to 5·10; it fuses before the blowpipe with difficulty. In powder it is perfectly soluble in warm hydrochloric acid. Its chemical composition is—

		Centesimally.
3 Eqs. iron,	81	71·68
4 Eqs. oxygen,	32	28·32
1 Eq. magnetic oxide,	113	100·00

corresponding to the formula Fe_3O_4, or $Fe_2O_3 + FeO$. The last is considered to be the true formula, expressing a combination of one equivalent of sesquioxide and one of protoxide. The analyses obtained of magnetic oxide of iron give—

Iron,	71·86	71·91
Oxygen,	28·14	28·09
	100·00	100·00

Specular Iron Ore—Red Hematite.—This is a sesquioxide of iron existing in great abundance, and found in a variety of shapes, both massive and in crystals. The following are a few of the crystalline forms in which it is found—Figs. 272, 273, 274. The crystals are of a dark steel-grey color, but leave a reddish-brown streak upon a stone or any hard substance; they have a specific gravity varying from 4·8 to 5·3; and are a pure sesquioxide, composed as follows:—

Fig. 272.

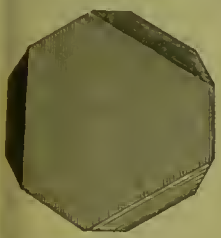


Fig. 273.

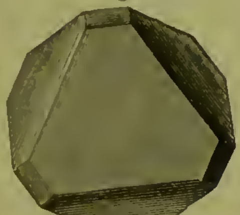
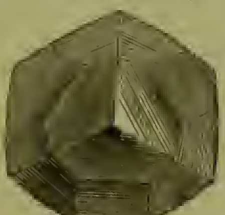


Fig. 274.



		Centesimally.
2 Eqs. iron,	54	69·34
3 Eqs. oxygen,	24	30·66
	78	100·00

This same oxide exists in a variety of other forms, such as a fibrous mass, with the fibres radiating from a centre, in which state it is termed the *red hematite* or *fibrous iron ore.* When the ore is an amorphous mass, it is termed *compact iron ore;* when mixed with clay and other earthy matters, *red ochre;* when hard, and combined with silica, *jaspery ore;* when in scales of a black metallic lustre, it is known as *micaceous iron ore* or *iron glance.*

This ore occurs both in the primitive and secondary rock; it abounds in the Island of Elba, Norway, Sweden, and Switzerland. Fine specimens are met with in the fissures of rocks in the volcanic districts. The red hematite, found in masses, having an unctuous feel, and readily soiling the fingers and everything with which it comes into contact, exists in many parts of England, particularly in Cornwall and Ulverston. This variety has generally from eight to ten per cent. of silica. It is wrought in great quantities along with poorer kinds of iron, and produces a strong metal. When subjected to a high heat alone, such as the jet of the blowpipe, it yields a portion of its oxygen, and is converted into the magnetic oxide. It is very slowly soluble in hydrochloric acid. The following are several analyses of this ore from different localities:—

Iron,	70·42	70·27	69·85	69.22	69·	68·96
Oxygen,	29·58	29·73	30·15	30.78	31·	31·04
	100·00	100·00	100·00	100·00	100·	100·00

Another form of the same oxide, in combination with water, is very abundant as a mineral known as *brown iron ore.* It has a brownish color, produces a yellow streak, and, when crushed, a yellow powder; it is thus easily distinguished from the anhydrous oxide, which yields a red-brown powder. It is of lower specific gravity than the red, varying in density from 3·8 to 4·2. It usually occurs in a massive state, and is composed of—

		Centesimally.
4 Eqs. iron	108	59·0
6 Eqs. oxygen	48	26·3
3 Eqs. water,	27	14·7
	183	100·0

This corresponds to the formula which is always given for the ore, $2\,Fe_2O_3 + 3\,HO$. The following are the results of three analyses:—

Peroxide of iron,	80·25	90·53	86·34
Water,	15·00	9·47	11·66
Silica,	3·75	—	2·00
Loss,	1·00	—	—
	100·00	100·00	100·00

Brown iron ore is found both in amorphous masses, and in crystals of a variety of forms, according as the ore may have been produced either by the decomposition of iron pyrites, or substitution and oxidation of carbonate of iron. It also occurs in small rounded pieces, either loose or conglomerated, in which state it is known as *pea iron ore.* When mixed with clay and other earthy matters, and of a soft texture, in which state it is found in great beds, it is termed *yellow ochre.* It exists in great quantities in Normandy, Berry, Lorraine, Burgundy, and constitutes the principal supply of ore for many of the French ironworks.

BOG IRON ORE.—This ore is amorphous, having a vitreous lustre, yellowish and dark-brown in color; it is of very recent formation, and is produced from the decomposition of certain rocks over which water passes; it is therefore always found in low marshy places, and hence its name. The following are the results of analyses of this ore from different localities:—

Sesquioxide of iron,	78·57	43·4	66·0	66·33	51·0	70·05
Protoxide of iron,	—	—	—	3·60	—	—
Lime and magnesia,	—	—	—	—	—	2·43
Oxide of manganese,	—	15·0	1·5	0·75	—	1·78
Phosphoric acid,	—	—	8·0	0·12	10·99	0·34
Water and organic matters,	21·43	15·0	23·0	26·40	28·80	15·87
Silica,	—	23·0	—	2·80	9·20	8·03
Alumina,	—	3·2	—	—	0·41	1·50
	100 00	99·6	98·5	100·00	100·40	100·00

Iron Pyrites.—The affinity between iron and sulphur is equal to that between iron and oxygen, varying according to the circumstances in which they are placed; under one condition, oxygen will take the iron from the sulphur, and again, under other circumstances, iron will leave the oxygen for the sulphur. That these conditions may have determined the different combinations in nature is a probable hypothesis. Sulphur and iron are combined in a great variety of proportions, and give rise to an important series of minerals, the most abundant being what is termed iron pyrites or bisulphide of iron. This mineral varies in tint, according to its exposure, from a yellow bronze to a silver white; the high bronze yellow hue may be familiar to every one in what is termed the sulphur in coal, which is iron pyrites; it has a metallic lustre, and is very hard, being capable of striking fire with steel, and therefore occasionally termed firestone; it is very brittle, and has a specific gravity of from 4·8 to 5·1. It occurs in beautiful cubical and octahedral crystals, some of which are represented by the following figures.

Different localities are known to give pyrites with a certain definite form of crystal peculiar to each, as for instance, the Island of Elba, which yields pyrites in crystals extremely large, and often of a pentagonal dodecahedron form, while some of the Cornish mines abound more in cubical crystals. A familiar instance of this form is seen in the common slate, and is popularly termed, *slate diamond;* these are true cubes of iron pyrites. The composition of this mineral is:—

Fig. 275.

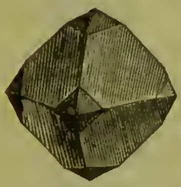


Fig. 276.

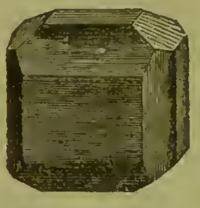
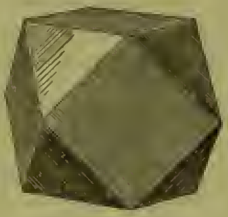


Fig. 277.



		Per cent.
1 Eq. of iron,	27	45·76
2 Eqs. of sulphur,	32	54·24
	59	100·00

expressed by the formula $Fe\ S_2$.

The various analyses of this mineral have given a composition which exhibits the following relations to the theoretical numbers above indicated:—

Iron,	47·85	46 08	46·53	46·5
Sulphur,	52·15	53·92	53·39	53·5
	100·00	100·00	99·92	100·0

Pyrites is very widely diffused through rocks. It has not yet been used as a source of supply for the manufacture of iron, but is most extensively employed for the making of sulphuric acid and alum—see Vol. I., p. 156. The residue of the heaps in making acid or alum is a sesquioxide of iron, with some remaining sulphur and earths, and is used as a coarse pigment for out-door purposes, under the name of *colcothar* or *purple* brown.

There is a certain kind of pyrites very common in the mineral districts, and found in round and sometimes curiously-shaped nodules in clay, which when broken has a radiated appearance of fibres proceeding from the centre, or sometimes from various centres, and is often either compact or granular. This sort is termed *white pyrites*, it being lighter in the color. It is also termed *cockscomb pyrites*, from its radiations. It has a density varying from 4·69 to 4·90. When analysed it is found to have the same composition as the other sort, but is much more liable to spontaneous decomposition. When exposed to a damp atmosphere, it often crumbles to pieces; the sulphur is oxidised and converted into sulphuric acid, which combines with the iron to form sulphate of iron or copperas, and appears as an efflorescence of minute crystals on the surface of the mineral. This sort of pyrites is very plentiful in Anglesea and several of the copper mines of this country. White iron pyrites is more liable to be impure than the ordinary kind, and when found in mines of other metallic ores, it is often impregnated with some of the other metals. That of Anglesea often contains both copper and zinc, and frequently small portions of silicious and argillaceous matter. A specimen analysed by Berzelius gave:—

Iron,	45·07
Sulphur,	53·35
Manganese,	·70
Silica,	·80
Loss,	·08
	100·00

Magnetic Iron Pyrites.—This is a sulphide distinct from the common pyrites. It is found mostly in masses filling up fissures of rocks, is seldom crystallized, and is not very abundant. Occasionally it is met with associated with common pyrites, but is distinguished from the latter by being of a deeper color, and also, as its name implies, magnetic. It has a density of 4·6, and is composed of—

		Centesimally
7 Eqs. of iron,	189	59·63
8 Eqs. of sulphur,	128	40·37
	317	100·00

represented by the formula, $Fe\ S_2 + 6\ (Fe\ S)$, which expresses a combination of bi- and proto- sulphide of iron.

The following are several analyses of this mineral which agree with the formula—

Iron,	59·29	56·38	59·61	59·72	59·8
Sulphur,	40·71	43·62	40·43	40·32	40·2
	100·00	100·00	100·04	100·04	100·0

Another iron pyrites is also found, which differs little from the common, except in the form of crystal; generally, however, it has a little of another matter in it, which is present more as an impurity than as forming a part of its constitution. This mineral is known as *marcasite*, and its composition by analyses is—

Iron,	45·07	45·60	45·66
Sulphur,	53·35	53·05	54·34
Manganese	0·70	—	—
Copper,	—	1·41	—
Arsenic,	—	0·93	—
Silica,	0·80	—	—
Loss,	0·08	—	—
	100·00	100·09	100·00

ARSENICAL IRON PYRITES—*Mispickel.*—This mineral is met with abundantly in Cornwall and upon the Continent. It is often associated with other metals, as tin. It is found in crystals, but more generally as an amorphous mass. It has a grey, silver-white color and metallic lustre, is very hard, and has a specific gravity of from 5·7 to 6·2. It is easily known from the strong smell of garlic it emits when struck by the hammer or rubbed on anything hard or heated. It is a combination of sulphur, iron, and arsenic, and is composed of—

		Centesimally.
2 Eqs. of Iron,	54	33·5
2 Eqs. of Sulphur,	32	20·0
1 Eq. of Arsenic,	75	46·5
	161	100·0

agreeing with the formula $Fe\,S_2 + Fe\,As$.

Another variety of arsenical pyrites is known under the technical name *Danaite*, differing from the above in having cobalt as a constituent. Its analysis from different localities does not vary much, as the following two examples show :—

Iron,	26·54	33·28
Cobalt,	8·31	6·52
Sulphur,	17·57	18·02
Arsenic,	47·55	41·86
Loss,	·03	·32
	100·00	100·00

Besides the few which have been described, there are several other sulphides of iron well known to mineralogists, either from their peculiar form of crystal or the state in which they are found combined. There are likewise a great variety of other minerals, being combinations of iron with other metals, as cobalt, nickel, *et cetera;* also with other matters, forming arseniates, silicates, and the like, some of which will be noticed in another part of this article. Amongst these may be specified copper pyrites, composed of copper, iron, and sulphur, but which is never wrought for the iron it contains, although yielding more of it than the ore which is generally worked for that metal.

CARBONATE OF IRON.—This is the most common ore of this country, from which the greater part of the iron is manufactured, and of which there are several varieties. The true carbonate, or *spathose iron ore*, often occurs crystalline, generally in well-shaped six-sided prisms, and rhombohedrons, similar to carbonate of lime; although more generally the ore is obtained in a massive state, with a foliated structure. It is mostly of a light-brown or grey color, having a pearly lustre, varies in specific gravity from 3·0 to 3·85, and is composed of—

		Centesimally.
1 Eq. protoxide iron,	35	61·4
1 Eq. carbonic acid,	22	38·6
	57	100·0

It is, therefore, represented by the formula $Fe\,O, CO_2$.

This mineral, however, often contains small portions of manganese and earthy matters, as the following analyses of samples from different localities will show:—

Oxide of iron,	53·06	49·61	59·63
Carbonic acid,	38·41	38·44	38·04
Manganese,	4·20	0·10	1·89
Magnesia,	2·26	5·18	—
Lime,	1·12	6·67	1·20
Silica,	0·48	—	—
Loss,	·47	—	—
	100·00	100·00	100·76

The most of the ores from which British iron is made consist of a carbonate found in beds in the coal formation, often alternating with the seams from which the coal is taken. This circumstance gives great facility to the manufacture of iron in this country, and is at once the cause of the superiority and cheapness of the metal. The great deposits of this kind of iron ore in Britain are those of Dudley in England, those of Wales, and of Lanarkshire and Ayrshire in Scotland. These ores are always massive, and generally contain several impurities, which, if not extracted, affect more or less the quality of the iron. They may be divided into two sorts :—

The first is the argillaceous or *clay-band* ores which contain a considerable quantity of earthy matter or clay, and these, when wrought by themselves, yield a weak and inferior quality of iron. They have a dark-grey color, nearly black, and a specific gravity varying from 3·17 to 3·41. The following analyses give a fair average of their composition taken from different districts :—

Protoxide of iron,	32·22	38·80	35·0
Carbonic acid,	32·53	30·76	25·5
Manganese,	—	0·07	0·3
Lime,	8·62	5·30	—
Magnesia,	5·19	6·70	1·6
Silica,	9·56	10·87	26·5
Alumina,	5·34	6·20	11·8
Sesquioxide of iron,	1·16	0·33	—
Carbon,	2·13	1·87	—
Sulphur,	0·62	0·16	—
Loss,	2·63	—	—
	100·00	101·06	100·7

Black-band.—The second variety of this kind of ore, which is known as *black-band*, was for a long time unknown, and was first pointed out by the late D. MUSHET. It differs from the clay-band in having less earthy matters, and being much blacker in color. Some kinds of this ore have a homogeneous appearance, while others have coaly seams running between, and round light-brownish matter, stratified or in nodules; the whole mass or seam of this sort being of a mixed brown and black. The following analyses of a few samples of black-band exhibits the difference between it and the clay-band or argillaceous carbonate :—

Protoxide of iron,	49·4	49·6	46·6
Carbonic acid,	35·2	30·4	30·1
Magnesia,	4·0	8·1	—
Alumina,	1·8	1·8	—
Lime,	—	—	6·3
Silica,	—	—	5·4
Coaly matter,	9·6	9·6	8·4
Loss,	—	0·5	3·2
	100·0	100·0	100·0

This class of ore is exceedingly valuable to the manufacturer, as the presence of the coal assists in some of the preliminary operations. These two ores, the black and clay band, are generally wrought together, and give iron of excellent quality.

A most valuable addition to our knowledge of the iron ores of the Northern and North Midland Counties of England has been recently given to the world, in the *Memoirs of the Geological Survey of Great Britain.* These are to be further extended, and the completion of the work will be hailed as a great boon by chemists and iron manufacturers. At the same time, unless these analyses of the ores be followed up by a similar investigation into the flux and fuel used, and the iron produced from the ores, the directors of the Museum of Practical Geology will only tantalise the manufacturers by an unfinished work:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Sesquioxide of iron, ...	49·57	—	95·16	90·55	86·50	94·23	1·77	1·45	2·3[illegible]	1·[illegible]9	1·[illegible]
Protoxide of iron, ...	10·77	49·47	—	—	—	—	35·38	36·14	41·77	[illegible]·38	3[illegible]·[illegible]7
Protoxide of manganese, ...	3·06	2·42	0·24	0·10	0·21	·23	·94	1·31	1·1[illegible]	·95	1·[illegible]
Silica, ...	6·64	4·93	5·66	7·05	6·18	4·90	19·13	17·37	8·93	12·16	13·[illegible]
Alumina, ...	·84	·06	·06	1·43	·30	·63	7·63	6·74	4·7[illegible]	6·42	6·13
Lime, ...	5·69	3·47	·07	·71	2·77	·05	3·35	2·70	2·55	2·26	2·12
Magnesia, ...	1·21	3·15	—	·06	1·46	trace	2·33	2·17	3·[illegible]	3·[illegible]	2·77
Carbonic acid, ...	14·49	37·71	—	—	2·96	—	25·41	26·57	31·39	29·38	2[illegible]·47
Phosphoric acid, ...	·01	trace	trace	trace	trace	trace	·48	·34	·75	·47	[illegible]
Sulphuric acid, ...	trace	trace	trace	trace	·11	·09	trace	trace	trace	trace	tra[illegible]
Bisulphide of iron, ...	·03	·08	trace	·06	—	·03	·18	·10	trace	trace	[illegible]
Water, ...	8·14	—	—	—	—	·56	1·85	1·77	1·70	2·[illegible]	1·[illegible]
Organic matter, ...	trace	trace	—	—	—	—	·23	2·40	·85	·54	[illegible]
Potash, ...	·05	—	—	—	—	—	·78	·65	·43	·37	·18
	100·80	100·29	100·19	99·86	100·49	100·50	99·46	99·71	100·34	98·80	9[illegible]

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XXI.
Peroxide of iron, ...	·79	1·49	2·18	2·16	1·47	1·42	2·30	2·69	3·40	3·60
Protoxide of iron, ...	33·72	37·99	35·74	33·56	38·97	28·27	40·01	33·31	39·55	39·92
Protoxide of manganese, ...	1·01	1·51	1·23	·96	1·09	1·02	1·26	2·18	1·50	·95
Silica, ...	16 02	10·04	16·06	17·13	11·90	3·55	11·19	17·24	10·22	8·62
Alumina, ...	6·41	5·57	7·09	8·49	5·93	2·31	5·91	8·85	5·65	7·06
Lime, ...	3·99	4·59	3·01	3·17	1·62	13·94	2·78	2·32	3·38	7·44
Magnesia, ...	5·49	3·37	2·96	3·06	4·82	9·27	2·85	2·44	2·88	3·52
Carbonic acid, ...	28·14	29·92	26·74	25·63	30·14	37·61	29·72	24·83	28·63	22·85
Phosphoric acid, ...	·41	·80	·66	·79	·48	·74	·34	·62	1·12	1·86
Sulphuric acid, ...	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Bisulphide of iron, ...	·13	·06	·05	·26	·05	·04	·09	·13	·05	·11
Water, ...	1·41	2·21	2·17	2·25	1·66	·90	1·57	2·57	1·75	2·07
Organic matter, ...	·36	1·42	·76	1·57	·30	·92	1·38	1·85	1·14	trace
Potash, ...	·47	·55	·66	·74	·67	·16	·34	·49	·68	·27
Titanic acid, ...	—	—	—	—	—	—	—	—	—	·03
	98·88	99·52	99·31	99·77	99·10	100·15	99·74	99·52	99·84	100·37

OVERMANN has the following remarks on the clay-band of America:—

The compact carbonate of iron, spherosiderite, argillaceous iron ore, has no relation externally with the sparry variety; it comprehends most of the clay ironstones of the coal measures, particularly those which occur in flattened spheroidal masses, varying in size from the dimensions of a small bean to pieces weighing a ton. The color of this ore is commonly a dirty blue or grey-brown, reddish-brown, and yellowish-brown; fracture close-grained, hard, streaked white or brown, blackens before the blowpipe, and if calcined, is attracted by the magnet. This carbonate of iron, though belonging to the coal formation, is found in various places in the tertiary strata. It is the principal ore from which iron is smelted in England and Scotland, and yields usually from thirty to thirty-three per cent. of iron. It is largely distributed over the United States—Pennsylvania abounds in it. It exists in Maryland, Virginia, Ohio, Illinois, North Carolina, and Kentucky. The difficulty of working this kind of ore in the blast furnace, may be assigned as the reason why it is not more generally employed. England and Scotland use it extensively, and work scarcely any other kind.

VALUATION OF IRON ORES.—The value of the ore depends upon two conditions:—first, the quantity of iron it contains, and, second, the amount of impurities or matrix. The character and properties of the impurities, and the extent to which they will interfere with the quality of the iron when manufactured, must also be considered. To ascertain these points, the ore must be subjected to testing or assaying. There are two methods of assaying, termed respectively the wet and dry.

Wet Method.—What is termed the wet assay is the most accurate, and may be performed by any ordinary operative, after a short experience. Although, in the first instance, the operator wishes only to ascertain the quantity of iron in the ore, still, that being only a part of the process for obtaining the whole of the ingredients, it will be better to describe here the complete analysis required for practical purposes. The mineral being ground, weigh fifty grains and put them into a flask or beaker; add pretty strong aqua regia, and then digest the whole on a sand-bath at a boiling heat for fifteen or twenty minutes; remove the vessel from the heat, and add a little water; after allowing it to stand several minutes, decant the clear solution; add to the undissolved residue as much acid and water as at first, and repeat the digestion; then put the two solutions together, pour the whole into a porcelain basin, and evaporate to dryness; next add two ounces hydrochloric acid, and two ounces water, digest for ten minutes, and pour the whole upon a paper filter, taking care not to lose any of the liquid; wash the residue upon the filter till the liquor passing through is free of acid; dry the filter, heat the contents in a crucible to redness, and then weigh. This gives the insoluble matter. The filtrate is now carefully divided into two equal proportions; to the one is added caustic ammonia in excess, and then filtered; the contents of the filter are well washed, and then dried; the liquid filtered through with the washing is to be kept. To the other half of the solution add caustic potassa till the iron is precipitated, then add a considerable excess, and boil the whole for ten minutes, filter while hot, and wash the precipitate with warm water till the alkali is all removed; the iron precipitate is then dried. These two iron precipitates are now heated to redness in a crucible, and weighed separately; the weight of the one obtained by potassa will be that of the sesquioxide of iron; the weight of the other will be the sesquioxide of iron and alumina, if any of that substance has been dissolved; the difference of weight will therefore indicate the alumina, which is noted down. The quantity of iron which the sesquioxide contains is known by calculating their equivalents, which are as ten to seven:—thus, if the sesquioxide obtained be 12·5 grains, then 10 : 7 :: 12·5 : 8·75, and this being in twenty-five grains, will make the per centage of the ore thirty-five.

To the solution filtered from the precipitate by ammonia, there is added oxalate of ammonia, so long as a precipitate is formed, if there be any; this is stirred well, and after heating the solution it is again filtered, and the precipitate washed and dried. This is the lime in the state of oxalate, which is converted into carbonate of lime by subjecting it to red heat in a crucible, and then weighed. As the carbonate is the condition in which the lime would exist in the mineral, no calculation is required. To the solution filtered from the lime is added a little solution of phosphate of soda; the mixture is well-stirred for seven or ten minutes, and then allowed to stand for an hour; if a precipitate is formed, it is filtered, well washed, dried, and burned at a red heat; this precipitate is the phosphate of magnesia. When burned and washed, the quantity of magnesia present in the mineral is known from the fact, that every 237 parts of the precipitate are equal to 85·4 magnesia.

When the ore is to be tested for sulphur, it is better to take a separate portion of the mineral—say twenty-five grains—and digest in two parts hydrochloric and one nitric acid, for half an hour, then dilute and filter, and add to the filtered solution chloride of barium—allow it to stand for an hour; any precipitate formed is sulphate of baryta, which is obtained by filtering, washing, and then drying and burning; every one hundred and sixteen parts of this precipitate is equal to sixteen parts of sulphur. If only the quantity of iron be required, then the operator need go no further than the first precipitate, but he will have to take potassa only, and proceed as directed above.

The preceding method is applicable to any of the ordinary classes of iron ore, such as the hematite, brown oxide, magnetic, *et cetera*. Sulphides are never used for the manufacture of the metal; but even these, such as the common pyrites, may also be tested in the same way.

A few years ago Professor FUCHS recommended, for ascertaining the value of iron ores, the following process, founded upon the fact that copper reduces sesquioxide of iron to the state of protoxide:—Take fifty grains of the powdered ore to be operated upon, and digest in strong hydrochloric acid till all the iron is dissolved—say about half an hour; then add by degrees about twenty-five grains of chlorate of potassa to oxidise the iron—neither nitric acid nor nitrate must be used for this purpose. When the iron is oxidised, the solution is brought to boil, then a clean slip of pure copper is added, which must have been previously weighed, and the solution is kept in ebullition to prevent access of air. After ten minutes' boiling, and previous to removing the undissolved copper from the solution, hot water is to be added till the vessel is quite full; this is to be poured off, and the vessel again filled with fresh hot water. The copper, which is generally covered with a brownish coating, is then carefully washed in cold water, dried at a gentle heat, and finally weighed; every four grains of copper dissolved indicates five grains of sesquioxide of iron present in solution; the quantity of metallic iron may then be calculated as already stated.

The advantages of a process of this kind are not only that it is simple and easy to perform, but the presence of any of the earthy matters, as silica, lime, alumina, or other metals, does not interfere with it; only, if the ore contains arsenic, this process will not answer. Much care must be taken not to prolong the operation, as copper is dissolved by the acid present in small quantity, and in that case the results cannot be relied on; yet many are able from experience to perform the analysis in this way with great accuracy.

Another simple process for testing the quantity of iron in an ore, based upon the reaction of the protosalts of iron upon permanganate of potassa, has been proposed by MARGUERITTE:—When a solution of permanganate of potassa is poured into a very dilute acid solution of protosalt of iron, the protosalt becomes converted into the sesquioxide at the expense of the oxygen of the permanganate, decoloring the solution. As long as any protosalt of iron remains, it is immediately decomposed in proportion as the solution of the permanganate is gradually poured into it, the liquor assuming a very pale yellow color, due to the sesquioxide of iron produced; but as soon as all the iron is oxidised, one single drop of permanganate suffices to impart a distinct pink color to the liquor, which indicates that the experiment is finished.

Permanganate of potassa is prepared as follows:—

	Parts.
Binoxide of manganese,	2
Chlorate of potassa,	1
Caustic potassa,	3

Mix the whole thoroughly, introduce the mixture into a Hessian crucible, and keep it at a low red heat for about two hours. The mass, which is of a dark-green color, is then reduced to coarse powder, and mixed with three or four times its weight of water; after stirring the whole, nitric acid, diluted with half its weight of water, is gradually added until the liquor assumes a fine violet color; it is then filtered through pounded glass or asbestos, and preserved in a glass-stoppered phial. The reason of filtering through asbestos or glass is because contact with organic matter, such as paper or linen, decomposes the permanganate. The salt is very stable, and may be preserved for a long time without alteration, provided always that it be kept in a glass-stoppered bottle, and contact with dust or any organic matter carefully avoided.

To make the permanganate of the proper strength, dissolve twenty-five grains of pianoforte wire—which may be considered pure iron—in about 1·500 grains by measure of pure hydrochloric acid. When dissolved, and the disengagement of hydrogen gas has ceased, dilute the solution with about one pint and a half of water. It is necessary to dilute the solution to this extent, and to operate in the cold, in order to guard against the excess of hydrochloric acid reacting upon the permanganate and disengaging chlorine; one thousand grains-measure of the solution of permanganate of potassa, prepared as before described, being introduced into an alkalimeter, it must now be gradually poured therefrom carefully, drop by drop, into the hydrochloric acid solution of iron just alluded to, stirring the liquor all the time in order to insure complete action, exactly as in alkalimetry.

On adding the solution of permanganate of potassa, the operator will perceive that, at first, it is decolored as fast as it is poured in; but the rapidity of action gradually diminishes, and, at last, it imparts to the liquor a pinkish tint, which indicates that the whole of the iron in the liquor is oxidised. The number of divisions which have been required to obtain that result is carefully observed; and supposing, for example, that fifty divisions of the alkalimeter have been required to oxidise the twenty-five grains of pianoforte-wire employed, it is evident that each division of the permanganate of potassa test-liquors represents half a grain of metallic iron.

But whatever may be the strength of the solution of permanganate, it is always easy to adjust it to any desired standard; if too weak, by concentrating it by evaporation at a gentle heat; if too strong, by diluting it with a suitable quantity of water, so that it may be brought as near as possible to such a strength that one measure of the alkalimeter may indicate half a grain of metallic iron.

Take twenty grains of the iron ore and reduce them to very fine powder by levigation; put them into a flask capable of holding about a quart of water, and pour into it about one thousand grains-measure of pure and fuming hydrochloric acid. The mixture is now moderately boiled until the ore has dissolved. Water is then poured in, so as to fill up about one-third of the flask; and the salt of iron is brought entirely to the state of protosalt, by adding about one hundred grains of pure zinc, or about sixty grains of sulphite of soda. After boiling for a few minutes, and as soon as the liquor no longer evolves an odor of sulphurous acid, and has become greenish or almost colorless, all the iron has passed into the state of protosalt. The solution is then diluted with a fresh quantity of water, so as almost to fill the flask, and the test-liquor of the permanganate of potassa is poured in, drop by drop, until the characteristic pink color is produced. The operator then reads off the number of divisions employed.

Let it be supposed, for example, that the test-liquor is of such a strength that each division represents half a grain of pure iron, and that twenty-two divisions have been required to oxidise the metal contained in the twenty grains of ore operated upon. It is evident that these twenty grains contain eleven grains, and consequently fifty-five per cent. of iron.

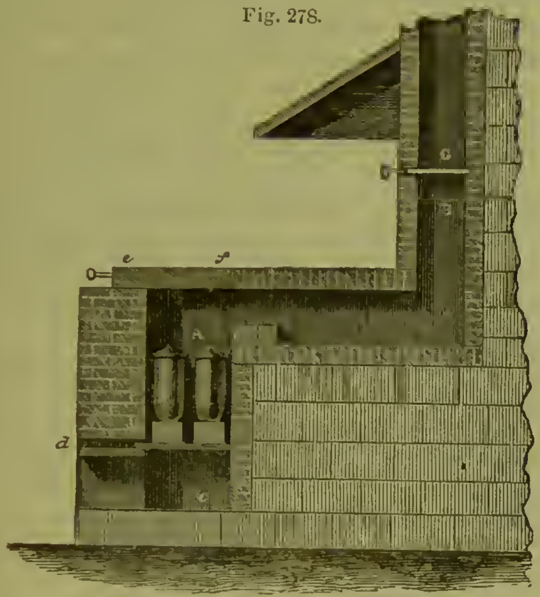
This process is obviously much more rapid than any of those previously described, and the presence of any other metal or earth does not interfere with the results—except two, namely, arsenic and copper Should either of these be present, they may be separated, previous to applying the test, by a bar of zinc, which precipitates them. Then filter the solution, and proceed as described.

The Dry Method.—By the preceding methods, it will be observed that it is the quantity of pure metal that is estimated; whereas, by the process of smelting, the metal is not obtained pure. Some metallurgists prefer using a process more analogous to the smelting operations for testing the value of the ore and the quality of the iron, and for this purpose practise what is termed the dry assay; this is performed by taking a sample of the ore and fusing it in a crucible, to obtain the iron in the metallic state. It will have been observed, that the ores generally contain small portions of silica, alumina, *et cetera.* Such matters are by themselves infusible; but at a high temperature they combine with the oxide of iron, and form a fusible compound; so that were the ore put into a crucible alone and fused, iron would not be obtained, but a combination of oxide of iron. It is necessary, therefore, to mix with the ore some matters that will combine with the substances named, and set the iron free. Such are termed fluxes and reducing agents; but even by the aid of these, the operation of assaying by the former requires great care, and necessarily a very high heat, the apparatus and operations for which are as follow.

The common assay furnace is of a very simple form. It is generally constructed upon the floor of the room, close to where there is a chimney, so as to insure a good draught. The following sectional sketch—Fig. 278—will give the best idea of its construction. A is the fire-place containing two crucibles; B, the chimney; *c*, ashpit open from the front for the admission of air; *d*, the grate bars; *c f*, cover for fire; G, damper for regulating heat.

The grate bars are loose pieces of bar-iron half an inch square, leaving an intervening space of the same size, and laid loose, so that they may be removed and the fire-place cleaned out, as the coals and bricks are apt to cake and choke up the fire-place. The latter should be lined with the best fire-brick built in with fire-clay.

Fig. 278.



and should be from sixteen to eighteen inches square, and from twenty-four to thirty inches deep. The fire is fed from the top, which is covered by a fire-clay tile, furnished with a rim of iron. The whole furnace should be strapped round with belts of iron, to prevent its splitting or falling to pieces by the expansion; or a very common method, and the most secure, is to fit them round with a cast-iron casing, which is a great preventive against the furnace rending and admitting currents of air. The most suitable fuel is a mixture of coal and coke. The furnace should be at a good heat before the crucibles are put into it. Some assayers place a small piece of tile or brick upon the bars on which the crucibles stand, while others embed them in the fire, which is the best method for obtaining an equal heat round the crucible. In a furnace of the size stated, two or three crucibles may be placed in the fire at a time, and this is often recommended; but the Editor prefers to use only one at a time, as giving the most certain results, though requiring a little longer for the operation. The most refractory kind of crucibles should be used; those termed the Cornish and Hessian answer very well. A good assortment of them, laid in a warm place, should be kept on hand by the assayer. Covers are also prepared for them, by baking a piece of fire-clay into the required shape and size.

For the purpose of inserting or removing the crucibles from the furnace, a number of different-shaped tongs are wanted. There are also required the following fluxes and reagents—pounded charcoal, slaked lime, potassa and soda, tartar, borax, and ground glass. If the assayer has a knowledge of chemical operations, he will, before making an assay, ascertain by means of tests, as already referred to, an approximate idea of the quantity of lime, silica, and alumina present, so as to regulate his fluxes; but it often happens that the assayer is ignorant of this, and he consequently judges of the quality of the ore and the fluxes to be used by the appearance of the ore when ground and burned. The assay is then proceeded with, by first taking a sample of the ore and grinding it fine in an iron mortar, weighing out two hundred grains, and placing it, mixed with an equal quantity of dry slaked lime and fifty grains of powdered charcoal, upon a clean piece of glazed paper; but if the ore be a refractory one, a little carbonate of soda or potassa may also be added.

The crucible should be previously prepared by filling it with pounded charcoal, moistened with water; this should be pressed into the crucible, and dried. A hole is scooped out in the centre of the charcoal, so as to leave about one quarter of an inch of charcoal all round. The mixed ore and flux are put into this cavity; the crucible is covered and luted with clay, and then placed in the centre of the furnace, the fire of which should have been allowed to burn low. When the crucible is properly embedded, coal and coke are packed all round and over it, filling the furnace nearly to the top; the crucible being as nearly as possible in the centre of the fire. For a time the fire is allowed to burn slowly, so as to drive off all damp from the ore and crucible. After a while the fire is covered, and the heat raised to the highest pitch and continued for about half an hour, when the cover of the furnace is removed, and a portion of the fire is taken out from the top, to expose the crucible, which is then withdrawn by a pair of tongs, giving it a gentle tap upon the floor, to shake down any particles of fused metal. When cool, the lid is taken off and the contents examined. For this purpose the crucible is generally broken; if the temperature has been sufficient, a small button of metallic iron will be found under the slag; if the heat has not been high enough, or a proper supply of flux has been wanting, the slag is full of small metallic beads, or the whole forms an agglutinated mass; in the latter case, the only remedy is to repeat the operation. If the process is successful, the small button of iron is carefully detached and hammered, to drive off any scoria adhering. The success of the whole operation is judged of by the appearance of the slag; it should be a greenish or greyish glass. This should be ground fine and spread upon paper, and a magnet drawn over it to detect any little prill of iron which may have remained in the slag. The whole iron is then weighed and the per-centage calculated. Iron thus obtained is not perfectly pure, but in general it is as pure as cast-iron, and may therefore be taken as the true valuation, if cast-iron is to be made from the same ore.

MUSHET, in his work upon iron and steel, enters extensively into the assaying of different ores by the furnace; he arranges the ores for assay into three classes —*argillaceous*, *calcareous*, and *silicious*—according to the earthy matters that prevail, so that there may be a proper distribution of flux, and each class is divided into two varieties, as follows:—

	First variety.	Average proportion.	Second variety.	Average proportion.
Argillaceous iron ore,	Clay,	9	Clay,	10
	Lime,	6	Silica,	7
	Silica,	3	Lime,	3
		18		20

For every four ounces troy of this class of ore, he recommends as flux the following ingredients well mixed:—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,	4	4
Chalk,	3	4
Charcoal,	0·50	0·75

Second class of ores :—

	First variety.	Average proportion.	Second variety.	Average proportion
Calcareous iron ore,	Lime,	14	Lime,	10
	Clay,	6	Silica,	6
	Silica,	4	Clay,	4
		24		20

The flux recommended for this class is—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,	5	4
Chalk,	1·50	2
Charcoal,	0·75	0·50

Third class of iron ores is—

	First variety.	Average proportion.	Second variety.	Average proportion.
Silicious iron ore,	Silica,	12	Silica,	10
	Lime,	8	Clay,	7
	Clay,	5	Lime,	5
		25		22

Flux recommended for four ounces of ore:—

	First variety. Ounces.	Second variety. Ounces.
Bottle-glass,	3·50	3·50
Chalk,	3	2·50
Charcoal,	0·75	0·50

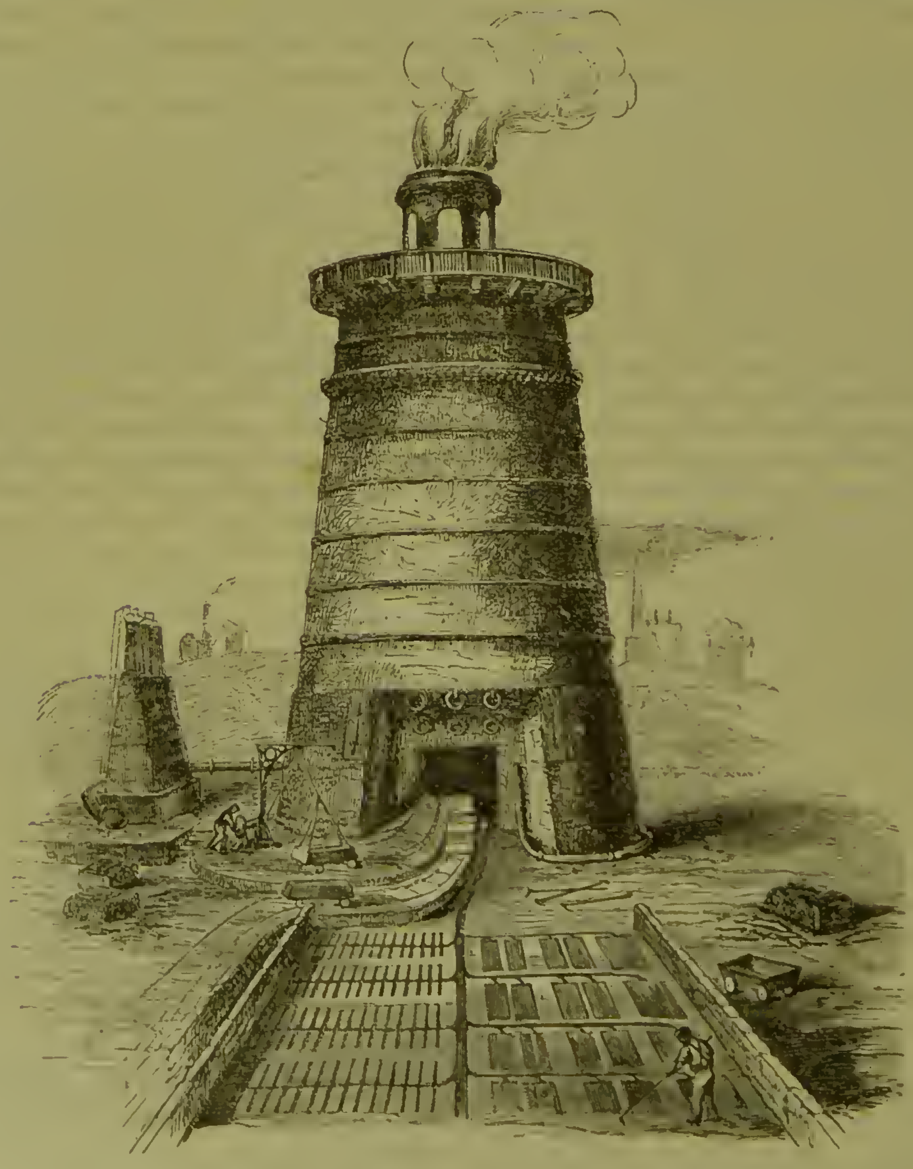
For hematite and such like ores that contain small portions of silica, the best flux for four ounces is—

	Ounces
Chalk,	1·50 to 2·
Charcoal,	0·50

Many assayers use slaked lime alone: others add with the lime small portions of the alkaline carbonates, or borax, which often facilitate the fusion, especially with such ores as contain much silica and alumina, and are, consequently, very refractory.

The button of iron obtained in the assay is subjected to the following test:—It is placed between a fold of thin tin-plate, to prevent it flying away on being struck. it is then hammered upon an anvil and broken; if the button flattens before breaking, and the fracture have a greyish appearance, the quality is considered good; but should it split on the first blow of the hammer, and show a crystalline fracture, white in color, it is not good, and the ore is judged unfit for the best quality of iron.

Fig. 279.



MANUFACTURING OPERATIONS.—Iron is produced for the purposes of the arts in three different states—as *crude* or *cast-iron*, *steel*, and *malleable* or *bar-iron*. These three modifications are the results of several and separate operations, undertaken for the express purpose of obtaining the quality of iron desired; although, when each is tested separately, they are found to differ only in the quantity of carbon or charcoal in their composition. Malleable iron is the purest, and has very little carbon in it; to have it quite pure is the aim of the manufacturer, but this is never accomplished in practice. Steel contains more carbon than bar-iron, and cast-iron generally more than steel; but there is no fixed proportion of that ingredient in either by which a line may be drawn between them; they seem to merge into one another, so that some kinds of steel may be called cast-iron, and some cast-iron may be considered steel. The difference is often more dependent upon the mode in which the carbon is combined with the iron, than on the exact quantity present. Ordinary crude or cast-iron contains, also, other impurities, as silica, which render it very inferior; and the variable amount of silica and carbon found in different kinds, gives rise to a great variety of qualities of cast-iron, distinguished by technical names, such as *grey*, *mottled*, *white*, *silver*, *et cetera*.

The manufacturing operations succeed each other in the following order:—1. The calcination of the ores, by which the carbonaceous and volatile matters are burned off, and the whole reduced in bulk to prepare them for the smelting furnace; 2. The extraction or reduction of the metal in the form of cast-iron by smelting; 3. The conversion of the cast-iron into malleable or wrought iron by puddling and rolling; and 4. The reconversion of the comparatively pure malleable iron into that particular carbide which is known as steel.

CALCINATION OF THE ORES.—The carbonated ores of this country are generally prepared for the blast furnace by a process of calcination which burns away all volatile matters, and concentrates the metal. For this purpose the ores are accumulated in large heaps, generally in an open field, and mixed with carbonaceous matters, such as small coal. Some of the black bands have sufficient coal in their composition to effect their calcination. After a heap of several hundred tons is collected, a fire is kindled at the windward end, which gradually passes on through the whole mass and burns for several days, producing a very high heat, often sufficient to reduce and fuse some of the metal, which, however, is not desirable.

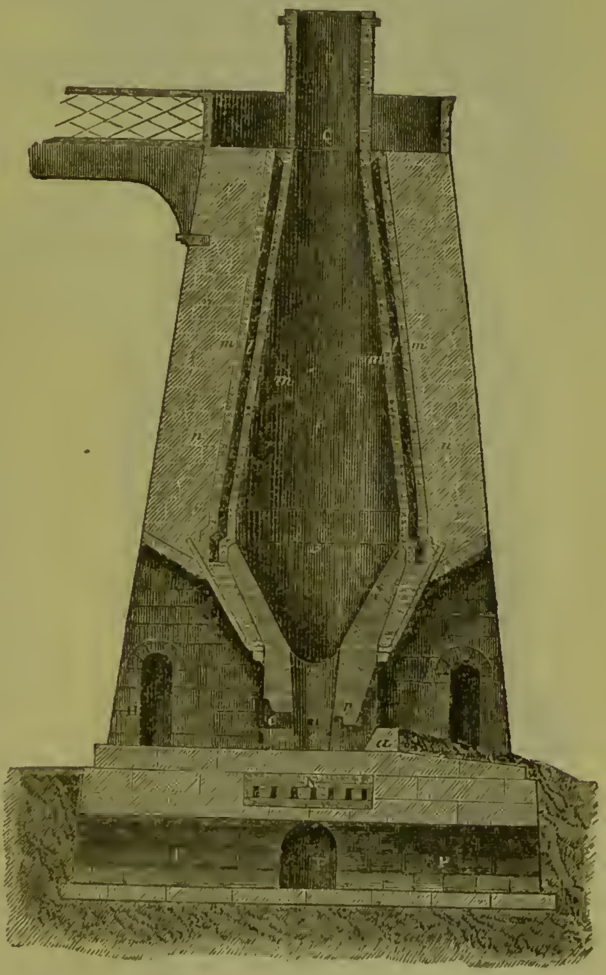
The black-band iron ore, of the average of thirty-three per cent. of iron, will contain, after calcination, an average of seventy per cent. of iron. The clay-band of thirty per cent. of metal in the ore, will, when properly calcined, contain about fifty-four per cent., so that by this means a great saving is effected in the amount of fuel required for the subsequent operation of smelting.

Instead of roasting the ore in open heaps, the same operation is sometimes performed in kilns, similar to those used for burning lime. In some districts, this method is found more convenient than large open heaps, covering often several hundred square yards.

SMELTING THE ORES.—The next operation is the smelting or reduction of the calcined ore, and the first subject which falls to be considered under this head is the form and *materiel* of the furnace.

The structure of the blast furnace varies considerably in different localities, according to the views of the smelter and the character of the ore and fuel, but in their general features there is much sameness. Drawings will be given of a few of the forms adopted at different times and in different places; but to enable the reader to understand the references to particular parts, it may be well to introduce, in the first place, an external and sectional view of a blast furnace of modern construction. The former is shown in Fig. 279, including the sand-bed in which the metal flows, to form the pigs of cast-iron as they are taken to market. Fig. 280 is a section of a similar furnace, consisting of two courses of fire-brick, *m m m m*; between these is a casing, *l l*, of pieces of brick, scoria, and sand. Over the whole is the external coating of thick masonry, *n n*, formed either of ordinary bricks or of stone, as is most convenient. The inside lining of fire-bricks is technically termed the shirt of the furnace; the part extending from the cross line at B, and running down into the crucible portion at E, is composed of fire-stone; occasionally fire-bricks of the most refractory sort are used for this part also. The small part at E is termed the hearth; the bottom is formed of a large fire-stone, supported by a mass of mason-work, having air-channels, as seen at N, while open arches or galleries, PPP,

Fig. 280.



are made below, one intersecting another at right angles, to keep the whole erection dry. D is the chimney surrounded by a gangway, with openings to admit the barrow, by which the furnaceman introduces the ore, flux, and fuel. C is the *throat* or *trunnel* hole of the furnace; A is called the cone or body; B the boshes; H H are arches leading through from one tuyere-hole to another, for convenience in attending upon the furnace. One of the stones composing the hearth, as shown at *r*, does not reach the base, but is supported by a strong bearer of iron built into the masonry, on which rests a block of sandstone called the *tymp*. Below, and a little in advance, is placed what is termed the damstone, *a*. The sides of the hearth are perforated a little above the level of the tymp with holes, *c c*, for the admission of the discharging orifices of the blowing apparatus, termed *tuyeres;* the arrangements of which will be shown in a future figure.

The preceding details will enable the reader to appreciate the points of resemblance and of difference in the following furnaces.

Fig. 281 represents a furnace which at one time was very common in Europe, and some specimens of which still exist in Spain and Hungary. It is exactly in the form of two crucibles, the one inverted over the other. This furnace measures from ten to sixteen feet in height, two feet wide at bottom and top, and five feet in the centre; two tuyeres are seen at *a a*, which admit the nozzles of two pair of bellows; in the front is an opening about two feet square, which, while in work, is built up with brick. After the furnace is heated sufficiently to permit the descent of the partially-fused metal, it is charged with the ore and charcoal fuel, and this is continued till, from the quantity of ore put in, the reduced metal would be up to near the tuyeres. The blast is then stopped, the front part, or breast wall, built up with brick, is removed, and the iron, which exists in a solid mass, is loosened and removed by crowbars, and then carried to the forge hammers and wrought up into bar-iron. The front is again built up, and the smelting operations renewed. From the state in which the iron is obtained, this furnace has been named the *salamander* furnace.

Fig. 281.

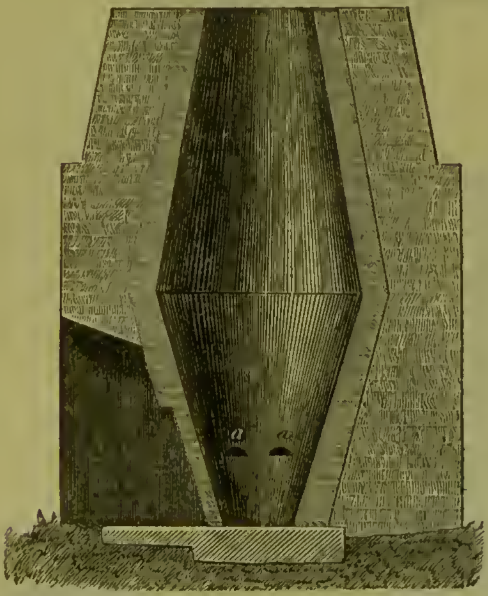
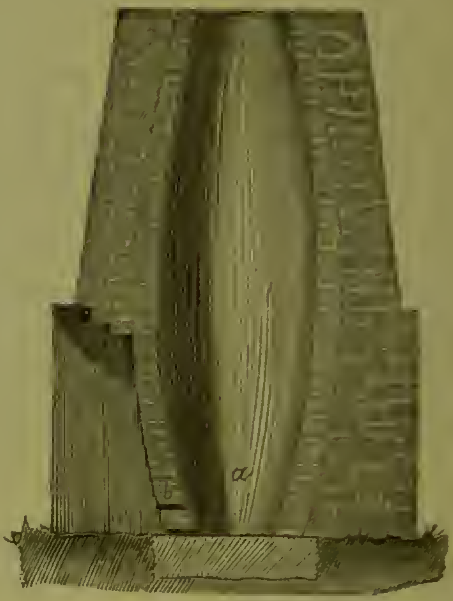


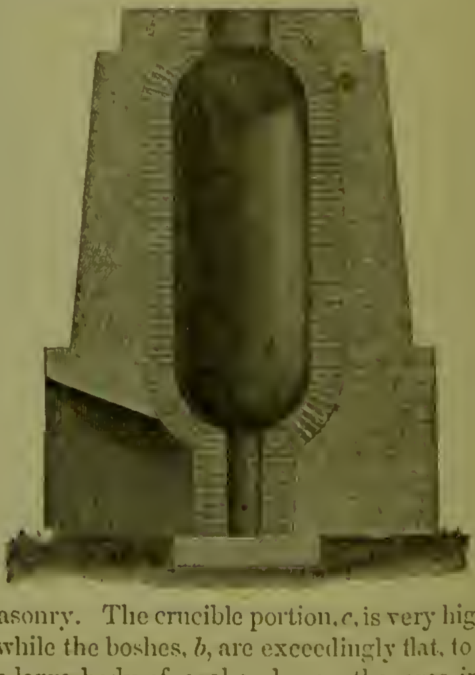
Fig. 282 represents what is termed the *blue oven* This kind of furnace is in common use in Germany, and approaches near to our ordinary blast-furnace in the internal shape; its height is from twenty to twenty-five feet; *a* indicates the tuyere holes; it is also furnished with a breast, which can be removed; at the bottom, however, is a small hole, to let out the fluid metal; and a little above this, another to enable the scoria to be taken out. The bottom of the furnace is made to slope to the tap-hole. The fuel used is charcoal. This is considered an excellent furnace for spar-iron ore, and yields a good steel-iron.

Fig. 282.



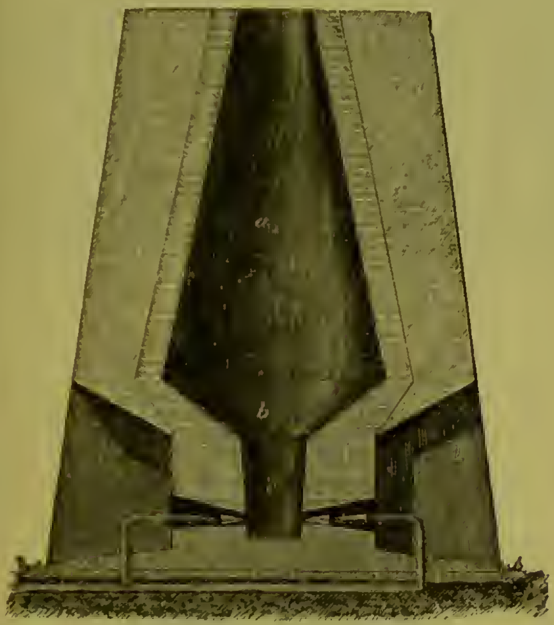
The form of furnace used in the Hartz mountains is shown in Figs. 283 and 284. It is constructed of very heavy masonry. The crucible portion, *c*, is very high and narrow, while the boshes, *b*, are exceedingly flat, to allow of a very large body of coal and ore; the ores in that locality being very refractory, composed mostly of red

Fig. 283.



and brown hematites and carbonates. The metal is let out from time to time in a fluid state, and is celebrated for its superior quality over most other irons.

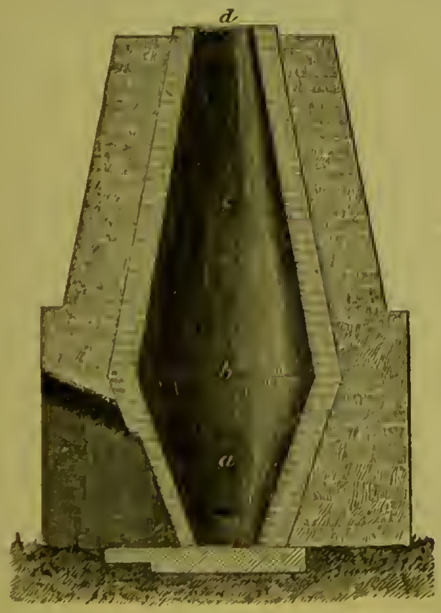
Fig. 284.



This form of furnace is used in Prussia and other localities for smelting bog-iron ores. It differs materially from all the other blast furnaces in its internal shape; the hearth or crucible part, however, resembles that of the one last described. The height of the furnace is about thirty feet; the crucible portion at the bottom is slightly tapered, its length being about six feet, and one and a half feet wide. Iron of very good quality is made from the bog-ore in this furnace, the fuel being charcoal.

Fig. 285 exhibits the structure of a furnace used in Styria for the smelting of sparry iron ore. The total

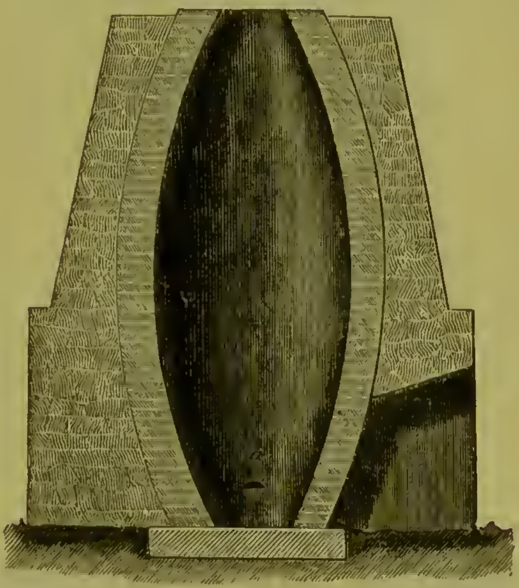
Fig. 285.



height is about thirty-four feet; the boshes, *b*, are about nine feet, and the top and bottom about two feet six inches diameter. The blast is produced by square wooden bellows, driven by water wheels. The iron is tapped out at intervals in quantities of from two to three hundred pounds weight. Charcoal is used as the fuel, and the best quality of metal is produced in these furnaces.

Fig. 286 represents the old blast furnaces of Sweden, which were known to have produced good iron, but in

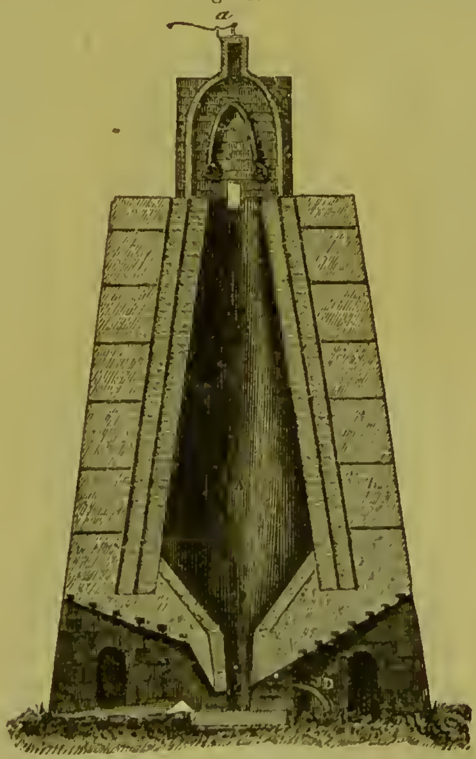
Fig. 286.



small quantity, not exceeding three tons per week. At the present time the furnaces of Sweden are similar to those used in England.

Fig. 287 shows the interior of a furnace used in

Fig. 287.



different parts of Germany, which is a very close approximation to the most improved furnaces of this country.

Fig. 288 is a blast furnace in Silesia. It is twenty-seven feet high, and is blown with hot-blast heated at the top of the furnace. The crucible portion resembles some of those already given; it is seventeen inches wide at bottom, and twenty-eight inches at top; the boshes are nine feet in diameter, the mouth or top three feet. The tuyeres are fifteen inches above the bottom stone. The ore used is the hydrated oxide of iron, and the fuel pinewood charcoal. This furnace is remarkable for the small amount of fuel required, and the production of a very fluid metal, excellent for fine castings, and much used for the manufacture of the celebrated Berlin castings.

Fig. 288.

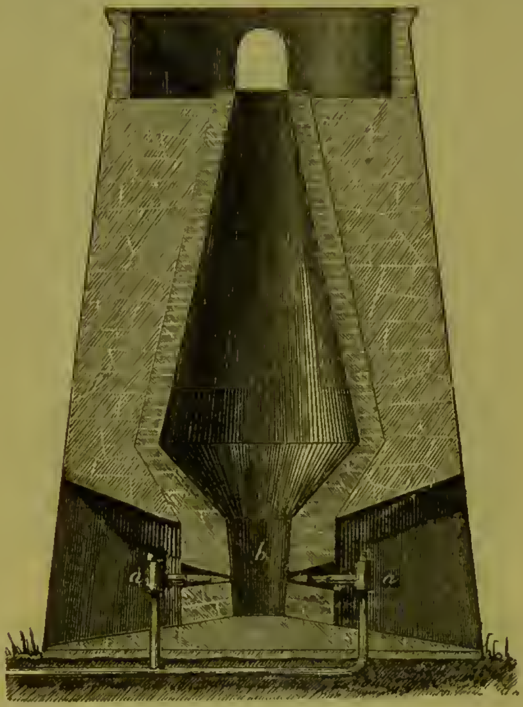


Fig. 289.

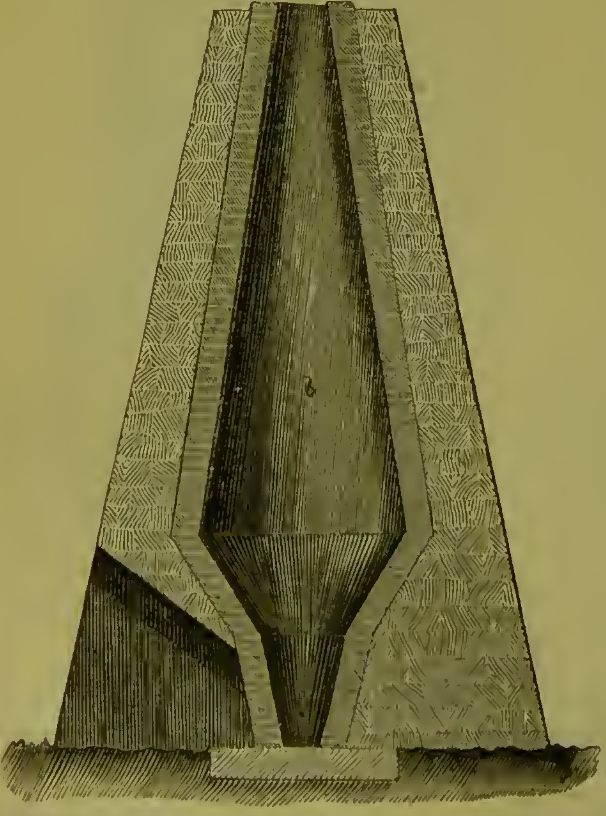
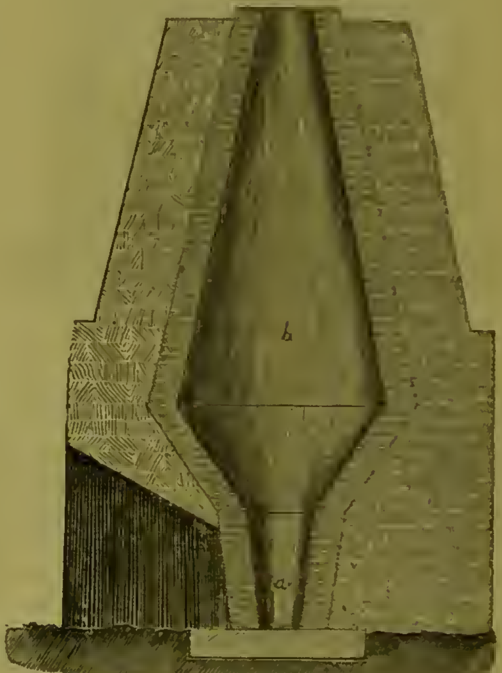


Fig. 289 is a charcoal blast furnace at New York; it is forty feet in height, and nine feet in width at the boshes; its hearth is six feet six inches high, and one foot nine inches wide. The ores wrought are mostly the magnetic oxide and brown hematite, with a small quantity of bog-iron ore. It produces a good quality of grey iron, very fusible. Two tons seven hundredweights of ore, and one hundred and twenty bushels of charcoal, are required to produce one ton of cast-iron.

Fig. 290 is another charcoal furnace, representing those in use at Pennsylvania in America. The height of this furnace, says Overmann, is thirty-two feet, width of boshes nine feet six inches, hearth five feet high, two feet in width at the bottom, and two and a quarter feet at top. The rich hydrates, pipe ores, fossil ores, *et cetera*, are generally used. Two tons and a half of ore produce, on an average, one ton of metal; for each ton one hundred and eighty bushels of charcoal are required. The furnaces in operation at the oldest establishments West of the Alleghany mountains, such, for instance, as the Dover furnaces at the Cumberland river, Tennessee. are almost a true copy of those in use in Eastern Pennsylvania; both require the same amount of fuel, and both yield similar results. Going further West, there is a greater amount of coal used to produce a given amount of iron. For instance, at the Alleghany and Ohio furnaces, as far down as Hanging Rock and Portsmouth, one hundred and seventy to one hundred and eighty bushels of charcoal are considered sufficient to make a ton of iron, while in Kentucky and Tennessee from two hundred to two hundred and fifty bushels of charcoal are required to produce the same amount.

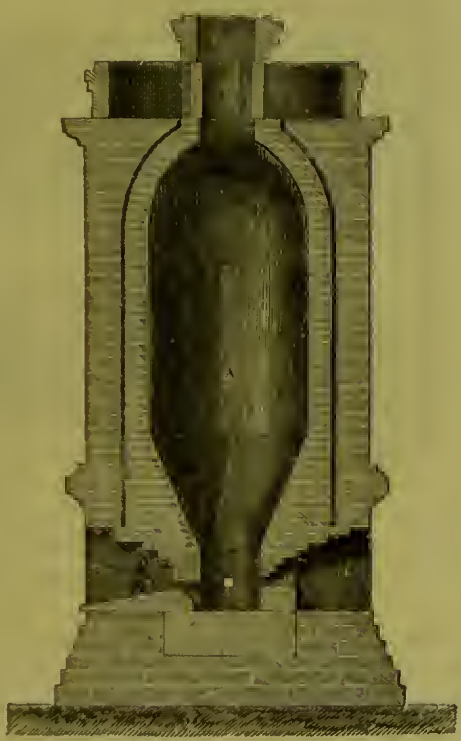
Fig. 290.



Such are a few of the different sorts of furnaces, fitted up as circumstances and locality have suggested, —all of them possessing certain qualities suitable to the conditions in which the work is conducted, and showing, what has been already stated, that the kind of fuel and ore often necessitates modifications in the furnace.

The furnaces at present in use in this country vary a little in their structure, according to the fancy of the builder, their early or recent construction, and whether originally intended for the cold or hot blast. A view of the general structure of the modern furnace has been already given—page 415. Mr. J. J. Griffin, in a series of interesting models of manufacturing apparatus for lectures, exhibits one of a blast furnace, similar to those employed in the neighborhood of Glasgow, where the hot blast is used. This is represented in Fig. 291, and will be seen to differ a little from any of the preceding, in having the body of the furnace more of a cylindrical shape.

Fig. 291.



The interior dimensions and measurement of two well-going furnaces, of the average size and structure used in this country, are thus tabulated by Dr. Ure:—

	No. 1. Feet.	No. 2. Feet.
Height from the hearth to the throat or mouth,	45·0	49·0
Height of the crucible or hearth,	6·5	6·0
Height of the boshes,	8·0	7·0
Height of the cone,	30·5	36·0
Height of the chimney or mouth,	8·0	12·5
Width of the bottom of the hearth,	2·5	2·0
Width at its upper end,	3·0	2·5
Width of the boshes,	12·5	13·5
Width at one-third of the belly,	12·0	11·5
Width at two-thirds of the belly,	8·5	9·5
Width at mouth,	4·5	3·5
Inclination of the boshes,	59°	52°

Materiel of the Furnace.—The bottom or hearth, which may be considered the crucible portion, or the part where the fused matters collect, is generally composed of a silicious stone found in the coal measures, termed millstone-grit, or fire stone, from its refractory character. The upper portion of the chamber is lined with fire brick.

The fire clay for making the bricks which line the furnace, and which is generally found in the same mine with the ironstone, varies very considerably in composition in different localities, having properties more or less suitable for the purpose, according to the absence of oxides, and the quantity of silica and alumina. Taylor, in his analysis of the rocks of the coal-measures at the Hartley pit, gives the following:—

	Fire clay.	Muscle bind.	Blue Shale.	Bituminous Schist.
Silica,	62·14	63·89	58·99	56·51
Alumina,	31·07	33·49	26·19	31·89
Oxide of iron,	2·24	—	10·25	7·04
Lime,	0·74	2·01	0·67	1·69
Magnesia,	0·83	0·61	1·54	0·85
Potassa,	2·45	—	2·34	1·38
Soda,	—	—	—	0·61
Loss,	0·53	—	0·02	0·03
	110·00	100·00	100·00	100·00

Dr. Richardson gives the subjoined analysis of the principal fire clays in the neighborhood of Newcastle:—

Silica,	51·10	47·55	48·55	51·11	71·28	83·29	69·25
Alumina,	31·35	29·50	30·25	30·40	17·75	8·10	17·90
Oxide of iron,	4·63	9·13	4·06	4·91	2·43	1·88	2·97
Lime,	1·46	1·34	1·66	1·76		2·99	1·30
Magnesia,	1·54	0·71	1·91	trace	2·30		
Water, and organic matter,	10·47	12·01	10·67	12·29	6·94	3·64	7.58
	100·55	100·24	97·10	100·47	100·70	99·90	98·90

Stourbridge has been long celebrated for its fire clay, which is admirably fitted for making crucibles and lining furnaces. The composition of various qualities of this clay as given by different analysts, along with fire clays from several other localities, is shown in the following table:—

	Stourbridge.			Monmouth.	Pembroke.	Govan.	
	Berthier.	Salvett.	Cowper.	Cowper.		Penny.	Penny.
Silica,	63·7	45·25	63·3	75·3	88·43	60·2	59·7
Alumina	20·7	28·77	25·3	16·8	6·90	37·7	37·5
Oxide of iron,	4·0	7·72	1·8	1·0	1·50	1·0	2·3
Lime,	—	0·47	1·5	0·9	3·40	1·0	1·0
Magnesia,	—	—	trace	—	trace	—	—
Water,	10·3	17·34	10·3	6·0	dried	dry	dry

For the sake of comparison, analyses of a few fire clays from different localities on the Continent are here added:—

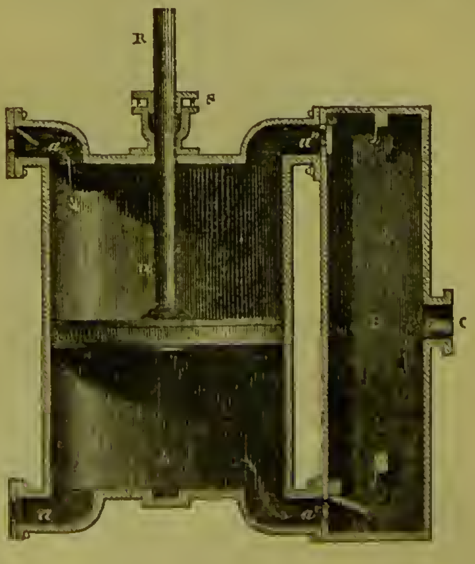
	Gross. Berthier.		Almerode. Salvetat.		Beaufoy's dep des Ardennes. Berthier.		Schlerdorf near Passau. Salvetat.
Silica,..........	46·5	..	47·50	..	52·0	..	45·79
Alumina,.......	34·9	..	34·37	..	27·0	..	28·10
Oxide of iron,...	3·0	..	1·24	..	2·0	..	6·55
Lime,..........	—	..	0·50	..	—	..	2·00
Magnesia,......	—	..	1·00	..	—	..	—
Water,.........	15·2	..	14·43	..	19·0	..	17·00

In making the bricks from these clays, they lose the water and become anhydrous; so that the character of the compound is thus considerably altered. Fire clay is also used as mortar for the inside lining of the furnace, which is subject to high heat. The outside work of the furnace is constructed either of common brick or stone, according as the one or the other is most easily procured in the locality.

The Blast.—Having described the various forms of furnaces, it will now be necessary to refer briefly to the mode of producing the blast. It has been stated that in olden times the pit furnaces, or *bloomeries*, as they were termed, were often made on the face of a declivity, having a frontage to the sea-breeze, with a proper construction for admitting the air; but that, by-and-by, bellows were used of various forms, according to the state of the arts; and that in the last century an improvement was effected, which completely revolutionized the smelting operations by the introduction of what is termed the cylinder blast, or *blowing machine*. This is made somewhat similar to the cylinder of a steam-engine, as shown in the annexed drawing—Fig. 292.

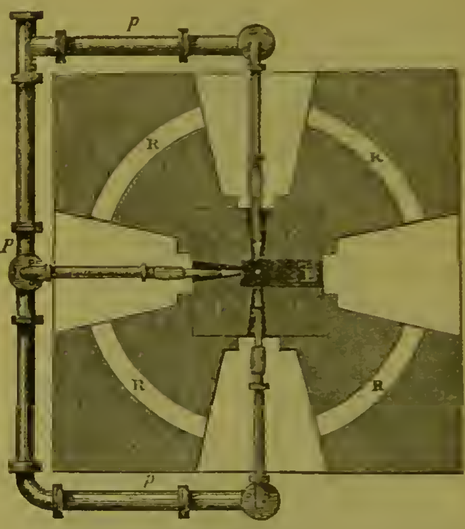
The cylinder is made of cast-iron, accurately turned inside, and fitted with a piston, made air-tight either by packing with hemp or gutta-percha, or by a metallic spring. It is closed at both ends; but the cover is provided with an aperture for the piston-rod, stuffed with leather or other suitable material to prevent the air from passing through. In the figure the piston is being forced down; the valve at a''' is open to admit the air from the external atmosphere; while the valve, a, is shut to prevent it being pressed out; and the valve, a', is open to allow the pressed air to pass into the chamber, B; while the valve, a'', is shut to prevent the pressed air returning to the upper portion of the cylinder. When the piston returns upwards, the conditions are reversed; the valves, a''' and a', are shut, and a and a'' are open; from the chamber, B, is a pipe, O, which conveys the blast to the tuyeres opening into the furnace.

Fig. 292.



To prevent the fusion of the nozzles of the pipes conveying the blast, the tuyeres are made of a hollow mass of cast-iron of a conical shape, through which flows a current of cold water. The nozzle of the pipe is connected with the main pipe by leather bands or rings.

Fig. 293.

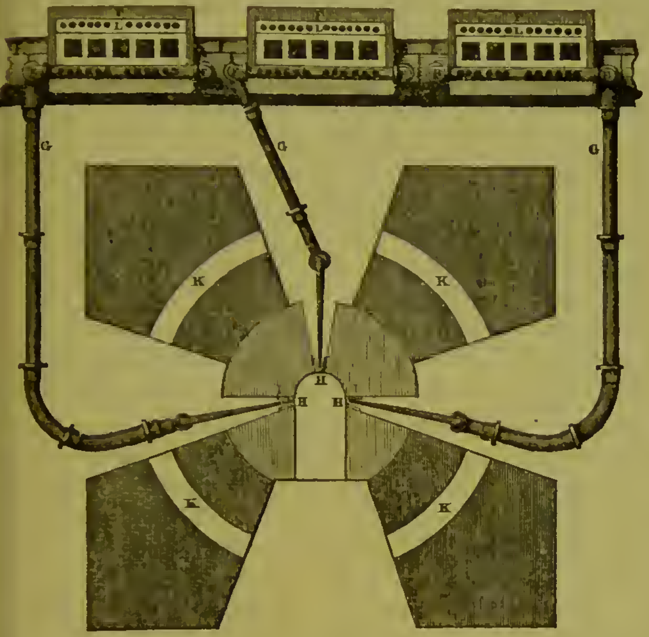


The tuyeres are generally three in number, entering the blast furnaces in three different parts. Care is taken, however, that although at the same level, they are not placed in such a position that the different currents should come into contact with each other in the furnace. The drawing—Fig. 293—will illustrate their position.

When cold-blast is applied, the air passes directly to the blast furnace; but when hot-blast is used, the air is made to circulate through pipes fitted into a large chamber furnace, by which the air is heated to several hundred degrees, and then admitted to the blast furnace. Fig. 294 will give an idea of the mode of heating the air in its passage from the blowing machine to the blast furnace.

The chamber in which the air is condensed by the blowing cylinder is large, and a considerable quantity of air is pressed into it, so that the blast entering the tuyeres is continuous. The pressure at which the air is thrown into the furnace varies, and smelters work with different pressures, according to the nature of the fuel employed and the season of the year. In summer a larger quantity is injected than in winter, owing to the air containing less oxygen in a given bulk in warm than in cold weather. The moisture of the air also affects the action of the blast—all which circumstances, even where the greatest care is taken, are found to cause considerable variation in the working of the furnace. Tho special effects produced by the nature and quality of the blast will be considered afterwards.

Fig. 294.



Having given a brief outline of the different forms of blast furnace and the blowing machine, it may be necessary further to mention in reference to the furnace, that when newly built, great care is required in bringing it to a heat. If the heat be raised too rapidly, the furnace is apt to crack and become damaged. A small fire is, therefore, kindled in the first place, and gradually increased till the wholo building is quite dry, by which time the fire in the furnace will be at the height of the boshes, requiring for this several days; then small quantities of ore are mixed with the fuel, and this is continued until the first portions of the ore have sunk to near the tuyeres, when the furnace may be said to begin its work.

THE FUEL.—The fuel employed in the blast furnace is either charcoal, coke, or coal. It has been shown that the first was almost exclusively used until the second half of the last century, when the introduction of the cylinder blowing machine, along with the steam-engine, permitted pit-coal to be most advantageous. It is true that, when this change was introduced, considerable difficulties were experienced in working the rich oxide ores; they fused too easily, and passed down into the mass of melted iron before the whole of the oxide was reduced to the metallic state. Experience, therefore, taught the smelter to use these rich ores in small quantities only, mixing with them the earthy and carbonated ores; and a more judicious apportioning of the flux has latterly enabled him more completely to overcome the difficulty.

The nature and qualities of different kinds of fuel have been fully discussed in a separate article devoted to that subject, to which the reader is referred for some important information in connection with its application to the smelting of iron ores. It is of the utmost importance that the metallurgist should have a thorough understanding of the nature and value of his fuel, otherwiso he will be always liable to variations in the production of his furnace. There is first to be considered the intensity of the heat to be obtained from a given bulk of fuel. This will be modified to a certain extent by the nature of the blast and the shape of the furnace; but coals that have much volatile matter in them lose this at a low heat, before the caloric which it would supply can act upon the lime employed as flux. Such coals are considered weak for smelting. Fuel containing much ash is also proportionally weak. The quality of the ash must likewise be considered with a view to the question, whether it contains ingredients deleterious to the iron; and also, whether the coal or coke contains any impurity, such as sulphur, which, though not remaining in the ash, may yet combine injuriously with the iron. When charcoal is the fuel, the only care of the smelter is economy, as far as consistent with the production of slags free from iron; for the ash or incombustible portion of charcoal is so small, and generally of such a character, as to be easily fused and taken up by the earths of the ore, so that there is little risk of any deterioration of the iron from this cause. Indeed the ash of charcoal is generally composed of such matters as form the best class of flux for the silica. In slags from the iron smelted with charcoal, there is generally nothing present but the pure silicate of lime, with a little potassa or other alkali, which may have been present in the ash of the charcoal. With coal and coke, however, the results are different. It will be seen from the analysis of coal, given under FUEL, that much of it contains small quantities of sulphur in the form of iron pyrites. Whether the coal be used raw or coked, the sulphur and the iron remain united, the sulphur being often amongst the last matters expelled by combustion, and only when the heat of the combustion is lower than will fuse the sulphide of iron; but, if higher, these will fuse together, and flow by their weight through the burning fuel, and, in the blast furnace, would mix with the iron; consequently, the presence of sulphur in the fuel is highly injurious, and ought to be carefully avoided. The ash of some coals being also considerable in quantity, constitutes a great proportion of the materials entering into combination in the furnace, either as scoria or with the metal. When fuel contains sulphur, or, as is often the case, the ore contains small portions of sulphur, a large excess of lime has to be added, which, when sulphide of iron is present and brought into contact, decomposes it, forming a sulphide of calcium, which is found in the slags or scoria. Yet, notwithstanding these reactions, the iron produced from coke and coal is seldom free from a small portion of sulphur, and is inferior to that made by charcoal.

Many processes havo been tried to free the coko used for smelting purposes from sulphur. Mr. CALVERT recently proposed to apply small portions of chloride of sodium to the coke in the process of manufacture, by which means the fuel was mado moro suitable for tho iron being freed from its sulphur, and in several experiments the iron made from this prepared coke was found much superior to the ordinary quality; but the process has not yet been very extensively adopted. Small portions of chloride of sodium have also been applied directly to the blast furnace, being injected by the blast, with results less or more favorable in different localities where tried. Carbonates of potassa and soda in small quantity, mixed with slaked lime, have also been injected into the furnace for the same object; but nothing as yet of any real practical value has been adopted to free the iron from the sulphur which may have combined with it from either the fuel or ore. It is true that its deteriorating influence is generally considered by the smelter to be greater than that of any other impurity; but this effect is probably exaggerated, as there are other impurities common to cast-iron, which are as injurious to the quality, and are present in greater proportion than the sulphur; some of these will be considered in a subsequent part of this article.

In a paper which was read by Mr. Fairbairn before the Society of Civil Engineers, the chemical action of the chloride of sodium added to the coke was thus described:—When coal was first subjected to heat in a coke oven, the bisulphide of iron contained in the coal was decomposed into sulphur, which latter was distilled or burned, and also into protosulphide of iron, which remained in the mass, and was acted upon by the chloride of sodium, as it was volatilized at a red heat; thus chloride of iron and protosulphide of sodium were produced. Then a second chemical reaction ensued: the protochloride of iron was decomposed into a subchloride of iron, and the chlorine gas, thus liberated, reacted on the sulphide of sodium, giving rise to chloride of sodium and to chloride of sulphur, which latter was disengaged—so that the prepared coke contained less sulphur than the ordinary coke; but admitting even that a small portion remained, it would be in the state of sulphide of sodium, which would not yield any of its sulphur during combustion, but passed into the cinders of the blast furnace or of the cupola, and the sulphur, thus fixed, did not enter into combination with the iron, preventing crystallization during the process of smelting, and giving greater tenacity and closeness of texture both to the cast and to the malleable iron.

The Flux.—It will be seen, by referring to the different qualities of the ores of iron, that mostly all of them contain small quantities of other matters; and that when these are silica and alumina, which are the most common, either separately or together, they are infusible in the blast furnace; but at a temperature below that of melting iron, they will combine with the oxides of other metals, and form with them combinations that are fusible. The oxides of iron combine readily with silica, and form a silicate of iron which is very easily fused. If, then, a mixture of iron ore and coal be put into the blast furnace, the reactions may be represented as somewhat like the following. Suppose a mixture is taken of clay and black band, composed as under:—

Oxide of iron,	80
Alumina,	13
Silica,	7

When these materials reach a temperature in the furnace sufficiently high to fuse a compound silicate of alumina and oxide of iron, the silica and alumina present will take up the required proportion of oxide of iron, and only the remainder of the iron will be reduced as metal, the silicates forming scoria; and thus a great quantity of the iron will be lost, varying according to the quantity of silica present in the ore. By a mixture of the iron ores above-mentioned, nearly one-third of the whole iron would be lost.

The object of the smelter is to obtain all the iron that exists in the ore. In order to effect this, it is necessary to put into the furnace, along with the ore, some matter that will combine with the silica in preference to the oxide of iron, and leave the latter to be reduced by the carbon. This must be some ingredient which can be procured in abundance at little expense, that it may not materially enhance the cost of producing the iron. The substance which best fulfils these conditions is limestone. Accordingly, in the smelting of iron on the large scale, lime is the only flux used; and fortunately it is generally found in abundance along with the ore, as the lowest bed of the coal formation in this country usually rests upon limestone. Thus, not only the ore, but the flux, and even the fuel itself, the blocks of refractory stone necessary for constructing the furnace, and the clay of which the fire bricks are composed, are often all found together—a provision calculated to excite the admiration of even the most unreflecting.

When lime and silica are subjected to a high temperature they combine easily, and form a fusible compound. The proportions in which lime and silica unite are various; but the heat required for their fusion differs according to the amount of lime present. If there is but a small quantity of lime compared with the silica, it requires a much higher temperature to fuse than if the former was in greater quantity than the latter. Taking the equivalent of silica at 46, then the weights which will be required to form a protosilicate with the following bases, are—

Slaked lime,	45
Limestone,	58
Fluor spar,	39
Carbonate of magnesia	34
Carbonate of potassa,	69
Carbonate of soda,	53
Protoxide of iron,	36
Sesquioxide of iron,	40

When alumina is combined with the silica, forming a natural clay, a much more compact and fusible compound is formed with the lime than when the silica is alone. Indeed, it has been observed as a general principle, that the point of fusion is materially affected by the relation and number of bases the whole materials contain: thus, a more liquid scoria is obtained by the addition of a limestone containing magnesia than with a pure limestone. But experience is against the use of a magnesian limestone, because it deteriorates the iron produced, while the purity of the metal is the primary consideration. That which contains much silica should also be used sparingly, as silica combines with the iron and injures its quality.

The purest limestones are the most suitable for flux. Common marble is nearly a pure carbonate of lime; but is too rare and expensive to be used as a flux.

Chalk is another very pure carbonate, and forms a most excellent flux, but is seldom used in large operations.

Oolite limestone, which derives its name from its being composed of small round grains like the roe of a fish, is another excellent and pure carbonate of lime.

Compact limestone, grey limestone, mountain limestone, *et cetera*, are very abundant, and are found of a great variety of colors, but never so white as the preceding, as they often contain carbon and oxide of iron, which are not detrimental as a flux.

There is another family of limestones termed the swinestone, and bituminous limestone; or sometimes *stinkstone* or fetid limestone, from its giving out an offensive smell when rubbed against any hard substance. This mineral is dark in the color, owing to the carbonaceous matters combined with it, and very hard; but when burned it is white, and forms an excellent pure lime and a good flux.

The following analyses of different limestones used as flux, selected from various sources, will give the reader the best idea of their variety:—

CONTINENTAL LIMESTONES.

	Calcareous spar from Andreasberg.	Coarse-grained limestone from Paris.	White granular limestone from Drebbach.	Chalk from Bougival.	Yellowish-grey limestone from near Lyon.	Shell-limestone, Muschelkalk, from Hollenhagen.
Carbonate of lime,	99·54	98·5	96·30	95·50	94·0	83·83
Carbonate of magnesia,	—	—	2·42	0·80	1·6	1·76
Protoxide of iron,	—	—	0·72	0·80	—	—
Protoxide of manganese,	—	—	0·40	—	—	—
Silica,	—	—	—	—	—	10·66
Alumina,	—	—	—	—	—	0·03
Oxide of iron,	0·36	1·5	trace.	1·70	3·9	1·73
Oxide of manganese,		—	—	—	—	0·06
Water,	0·10	—	1·20	1·20	—	1·93
	100·00	100·0	101·04	100·00	99·5	100·00

SUTHERLANDSHIRE.

	Assynt.
Carbonate of lime,	49·92
Carbonate of magnesia,	36·23
Oxide of iron and alumina,	4·70
Silicious matter,	7·92
Alkaline salts,	·20
Sulphate of lime,	·27
Loss,	·76
	100·00

STIRLINGSHIRE.

Carbonate of lime,	93·32	97·80
Carbonate of magnesia,	—	—
Sesquioxide of iron,	2·79	0·63
Carbonaceous matter,	0·28	0·64
Silica and alumina,	1·36	1·92
Loss,	2·25	—
	100·00	100·99

ARGYLESHIRE.

	Ardour.		Contyre.	Ban.
Carbonate of lime,	90·14	89·15	98·05	90·96
Carbonate of magnesia,	0·31	2·56	0·44	0·62
Alumina and oxide of iron,	0·51	0·51	0·29	1·81
Silicious matter,	9·08	7·48	1·27	6·40
Loss,	—	0·30	—	0·21
	100·04	100·00	100·05	100·00

INVERNESS-SHIRE.

	Beauly.	
Carbonate of lime,	93·82	94·10
Carbonate of magnesia,	1·64	1·00
Alumina and oxide of iron,	0·99	2·16
Silicious matter,	3·55	2·74
	100·00	100·00

NORFOLKSHIRE.

Carbonate of lime,	62·95	81·55	69·90	47·90	88·40
Carbonate of magnesia,	—	trace.	5·85	—	—
Oxide of iron and alumina,	7·40	4·65	6·45	trace.	4·55
Clay,	29·35	14·15	17·45	8·22	5·25
Loss,	·30	—	·35	3·88	1·80
	100·00	100·35	100·00	100·00	100·00

NORTHUMBERLANDSHIRE.

	Hastington.	Kirkheaton.	Belsay.	Allerwash.	Dryburn.	Oxford.
Carbonate of lime,	97·5	93·1	95·6	98·39	99·	96·2
Carbonate of magnesia,	·6	4·4	1·4	—	—	—
Silica,	1·3	2·2	3·0	2·40	1·	3·6
Loss,	·6	·3	—	—	—	·2
	100·0	100·0	100·0	100·79	100·	100·0

CUMBERLANDSHIRE.

	Cockermouth.	Brampton.	Kelhead.
Carbonate of lime,	94·86	94·56	95·95
Carbonate of magnesia,	1·26	2·32	0·54
Sulphate of lime,	0·23	0·32	0·24
Phosphate of lime,	—	0·33	—
Alumina and oxide of iron,	0·73	1·18	1·21
Silica,	2·92	1·29	2·06
	100·00	100·00	100·00

Many of the preceding analyses indicate small quantities of magnesia, which, when only a small percentage is present, may be used freely; but where it exceeds six per cent., it is better not to employ such limestones if others can be obtained; for although fluxing more easily than pure lime, they are considered to deteriorate the iron. The following are a few analyses of what are termed the magnesian limestone, which, for reasons already stated, ought to be avoided as a flux:—

	English.	Scotch.	Foreign.
Carbonate of lime,	54·50	53·09	55·36
Carbonate of magnesia,	44·93	43·49	41·30
Oxide of iron,	0·33	0·96	2·00
Silica,	0·24	2·46	0·50
Loss,	—	—	0·84
	100·00	100·00	100·00

Limestone also often contains much more silica than is shown in any of the above analyses; this is likewise a deleterious matter, as it combines with the iron and makes it very weak; consequently, limestone should all be tested previous to using it as a flux, which may be done easily. Good limestone should effervesce with great violence when put into dilute hydrochloric acid; magnesian limestone produces less effervescence. The best method of testing is to take twenty-five grains of the limestone ground and dried, and digest in a small glass flask with dilute hydrochloric acid till all effervescence ceases; the solution is then filtered, and that which remains upon the filter may be regarded as silica; this is to be dried and weighed. To the filtered solution add ammonia to neutralize the acid; this will precipitate the iron and any alumina in solution, but when these are in minute quantity the solution need not be filtered, as the presence of iron is as useful as lime. In this case, add, immediately after the ammonia, oxalate of ammonia, so long as a precipitate is formed; warm the solution, and after about thirty minutes, filter and wash; this when dried and burned at a red heat, gives the quantity of carbonate of lime. To the filtrate add a solution of phosphate of soda, which precipitates the magnesia, if any be present, as phosphate. This, after being filtered, dried, and burned, contains in every one hundred parts, 36·5 magnesia, equal to 76·7 of carbonate of magnesia—the condition in which it exists in the mineral. Thus the quality of the lime for fluxing can be easily ascertained; of course, as only twenty-five grains are used in this test, the results must be multiplied by four to get the per-centage.

Proportions of the Charge.—It has been stated that, in the assaying process, the iron is reduced from its ore by putting the mixed materials into a crucible, which is placed in the centre of the fire, so that the heat is applied to it externally. A blast furnace differs from a crucible, in so far as not only the ore and flux, but likewise the whole of the fuel, is thrown into it. For this purpose, men are constantly employed in wheeling the materials to the furnace in barrows made of sheet-iron, which are raised up by machinery to the platform round the mouth of the furnace, and their contents discharged into it, care being taken to keep the furnace full. Where tho ore is a mixture of clay and black-band with coal as fuel, tho charge is generally about the following proportions:—

	Hundredweights.
Calcined black-band,	4·5
Calcined clay-band,	4·5
Limestone,	1·5 to 2·0
Coal,	10·0

These are all mixed roughly and put into tho barrows. Sometimes the very large pieces of coal are broken into smaller ones; some smelters also break the limestone into small pieces of the size used for macadamizing roads; others think this unnecessary, from the fact that the limestone, when put into the furnace, very soon flies to pieces by the heat, and thus saves the labor of breaking by hand. Dr. URE gives the following as the practice in Staffordshire:—As soon as the furnace gets into a regular heat, the working consists simply in charging it at the opening in the throat whenever there is a sufficient empty space, the only rule being to keep the furnace sufficiently full. The coke is measured in a basket, thirteen of which go to the ton. In twenty-four hours there are thrown into a furnace, such as Fig. 280, fourteen and a half tons of coke, sixteen tons of roasted ore, and six and three-quarter tons of limestone, from which about seven tons of pig-iron are produced. But the exact proportions of the materials put into the blast furnace differ in every locality, and with every change of ore or coal.

Reactions in the Furnace.—The changes produced in the materials put into the furnace in their descent from the mouth to the hearth, where they are separated as iron and scoria, must be, to a certain extent, matter of speculation. It has been shown that the ores contain oxide of iron and silica, mixed with clay. A portion of these substances is often in a state of combination produced by the roasting operation. The lime is put in as a carbonate, which will not combine with the silica until the carbonic acid in union with the lime be driven off, and this does not take place till the limestone has descended to a considerable depth to experience the requisite heat. When lime and silica and oxide of iron are together, their combination depends upon the temperature to which they are exposed. The probability is, that the silicate of iron is the first compound formed, as it melts at a comparatively low degree of heat, and then in a melted state it trickles down, until it comes to a temperature sufficiently high to allow a simultaneous reaction of all the materials. From the results of analyses of cast-iron, it appears that a considerable portion of silicate of iron passes through the furnace without being decomposed, and mixes with the iron, rendering the metal impure. The scoria floats upon the surface of the metal, and as it accumulates, the furnace-man allows it to flow out by a hole in the side of the furnace, into large beds, where it is broken up for removal; or it is cast into large blocks and employed for building walls or any rough purpose. Every twelve hours the furnace is *tapped;* that is, the metal is let out into sand moulds of various shapes, but generally of a long semicircular form, known technically as pigs.—See Fig. 279.

The whole process of the action of the furnace is given by TRURAN as follows:—

The changes which occur in the descending ore commence with the uncalcined ores in the throat of the furnace; they lose their moisture and volatile gases before they reach the level of the boshes, absorbing from tho fuel the necessary caloric for calcination. Below this the ore is gradually converted from a sesquioxide to a magnetic oxide, or, as sometimes occurs, into metallic iron; having combined with a portion of the carbon from the fuel, to form the fusible carbide of iron. From the bottom of the boshes to the level of the tuyeres, the reduction of the ore and flux into a liquid mass is completed. The fusion of the ore and flux occurs at a height of eight or ten inches above the tuyere, from whence it descends into the hearth. Here the metal, from its greater specific gravity, falls to the bottom, freed more or less from the fluid cinder which floats on the surface, and protects it from the oxidising influence of the blast.

Gases Evolved.—The gases passing through and escaping from the blast furnace have been the subject of several investigations by the most eminent chemists. They were obtained by inserting into the furnace the end of a wrought-iron pipe through which the gases escaped, and were conducted by a leaden tube attached to the external extremity of the iron pipe into a pneumatic apparatus, where they were subjected to analysis.

The following are the results obtained by BUNSEN of Heidelberg, the fuel used being charcoal; the proportion of the gases is given in volume:—

Height above tuyeres. Feet.	Nitrogen.	Carbonic acid.	Carbonic oxide.	Light carbide of hydrogen.	Hydrogen.
17¾	62·34	8·77	24·20	3·36	1·33
16¼	62·25	11·14	22·24	3·10	1·27
14¾	66·29	3·22	25·77	4·04	1·58
13¼	62·47	3·44	30·08	2·24	1·77
11¾	63·89	3·60	29·27	1·07	2·17
8¾	61·45	7·57	26·99	3·84	0·15
5¾	64·58	5·97	26·51	1·88	1·06

Subjoined are the results of a similar experiment at Alfreton by Messrs. PLAYFAIR and BUNSEN. In this table the measurement is taken from the mouth or top of the furnace downward, extending to a depth of between one and two feet above the tuyeres:—

Feet from top.	Nitrogen.	Carbonic acid.	Carbonic oxide.	Carbide of hydrogen.	Hydrogen.	Olefiant gas.	Cyanogen.
5	53·35	7·77	25·97	3·75	6·73	0·43	—
8	54·77	9·42	20·24	8·23	6·49	0·85	—
11	52·57	9·41	23·16	4·57	9·33	0·95	—
14	50·95	9·10	19·32	6·64	12·42	1·57	—
17	55·49	12·43	18·77	4·31	7·62	1·38	trace.
20	60·46	10·83	19·43	4·40	4·83	—	—
23	58·28	8·19	29·97	1·64	4·92	—	trace.
24	56·75	10·08	25·19	2·33	5·65	—	trace.
34	58·05	0·00	37·43	—	3·18	—	1·34

The annexed table exhibits the relative proportion of oxygen and nitrogen at the different depths stated:

Feet.	Oxygen.	Nitrogen.
5	24·9	79·2
8	23·6	79·2
11	24·6	79·2
14	19·5	79·2
17	25·7	79·2
20	23·7	79·2
23	28·2	79·2
24	27·7	79·2
34	27·8	79·2

OVERMANN tabulates as follows the per centage of the different gases given off from a coke furnace:—

Above the tuyeres.	Nitrogen.	Carbonic acid.	Carbonic oxide.	Hydrogen.	Total.
2	61·07	0·68	36·84	1·41	100·00
17¼	64·66	0·57	33·39	1·38	100·00
28	63·59	2·77	31·83	1·81	100·00
31	60·70	11·58	25·24	2·48	100·00

The subjoined results are those obtained by Dr. SCHAFHAEUTL from the Ystalyfera anthracite furnaces:—

	Taken off one foot below the coal and ore in the furnace.	Taken off sixteen feet below the surface of the coal and ore in furnace.
Carbonic acid	9·546	00·136
Carbonic oxide,	12·012	18·974
Hydrogen,	21·278	27·834
Light carbide of hydrogen,	2·548	3·212
Sulphurous acid, with traces of arsenide and phosphide of hydrogen,	0·111	trace.
Nitrogen,	51·505	49·844
	100·000	100·000

In BUNSEN'S and PLAYFAIR'S elaborate report to the British Association for 1845, upon the theory of the blast furnace deduced from the examination of the gases, they conclude that the evolution of carbonic acid is owing to the reduction of the ore; and that the process of reduction takes place only in the boshes. The average proportion of the mixed gases must be somewhere between the following numbers:—

Nitrogen,	60·907	57·878
Carbonic acid,	8·370	9·823
Carbonic oxide,	26·846	24·042
Light carbide of hydrogen,	2·536	2·743
Hydrogen,	1·126	4·972
Olefiant gas,	0·112	0·392
Sulphide of hydrogen,	0·045	0·035
Ammonia,	0·058	0·115
	100·000	100·000

This mixture of gases contains:—

First. The products of distillation of the coal.

Second. The products of its combustion.

Third. The carbonic acid generated during the reduction of the ore, and expelled from the limestone.

WASTE PRODUCTS.—*Cyanogen.*—Another object of inquiry into the gaseous products of the blast furnace, besides the chemical reactions going on within, was to find if there could be any application of the products, and of the great quantity of heat given out at the mouth of the furnace. It will be observed in the analyses of the gases from the Alfreton furnace by Messrs. BUNSEN and PLAYFAIR, that cyanogen was detected at the lower portion of the furnace. They found in their experiments that when they withdrew the iron tube from this part of the furnace, it was incrusted with melted cyanide of potassium, which speedily deliquesced in the air. This led to inquiry as to the source of the potassium; and by very careful analyses of the ore and coal, these were found to contain small portions of alkali. The calcined ore gave—

Sesquioxide of iron,	60·242
Silica,	25·775
Alumina,	6·583
Lime,	3·510
Magnesia,	3·188
Potassa,	·743
Manganese,	traces.
	100·000

And the coal—

Carbon,	74·98
Hydrogen,	4·73
Oxygen,	10·01
Nitrogen,	0·18
Water,	7·49
Silicates,	2·61
Potassa,	0·07
	100·00

The presence of potassa is likewise shown in the table of the analyses of the North and North Midland ores given at page 410.

The formation of cyanogen gas by the direct combination of the nitrogen of the air with carbon at a high heat had been, previously to these experiments, pointed out by Dr. Fownes and Mr. James Young. The production of cyanide of potassium in the blast furnace, and the value of it as a product, were then calculated. The mixed gases, as already seen, possessed the following composition:—

Nitrogen,	58·05
Carbonic oxide,	37·43
Hydrogen,	3·18
Cyanogen,	1·34
	100·00

Every 219·33 cubic inches of gas must contain 1192·97 grains of carbon, corresponding to 1774·79 grains of coal. Hence, out of 100 parts of coal, at least 0·778 of cyanide of potassium is generated; and as 31,200 pounds of coal are consumed every twenty-four hours in the furnace, it is obvious that at least 224·7 pounds of cyanide of potassium are generated daily in the Alfreton furnace, and hitherto have been altogether lost.

Ammonia.—Another product obtained from the furnaces is ammonia. This substance, which is present in the gases of blast furnaces fed with coal, but never found in those furnaces fed with charcoal, is often in such abundance as to be sensible to the smell in the gases collected from the deeper parts of the furnace. Bunsen and Playfair remark that the ammonia may be obtained in the form of chloride of ammonium, if the gas, previous to its application as fuel, be conducted through a chamber containing hydrochloric acid. The advantage of its collection is, that without any further consumption of fuel, or any considerable expenditure of labor, a valuable commercial ingredient would be economized. The furnace coal of Alfreton was subjected to trials to ascertain the quantity of ammonia which might be produced by distillation, and the mean results gave 0·769 per cent.; and hence, the conclusions drawn were, that as two hundred and eighty hundredweight of coal were consumed in the furnace every twenty-four hours, not less than two hundredweight of sal-ammoniac might be obtained as a subsidiary product, without increasing the cost of manufacture, or in the slightest degree disturbing the process of smelting.

Application of the Waste Heat.—The great value of the investigation into the gases evolved from blast furnaces, was the economizing of the fuel, and the experiments proved the combustibility of the entire column of gas, from a depth of twenty-four feet to the mouth of the furnace; hence the gas collected at any point to this depth is capable of being applied as fuel. It was found that at the Alfreton furnaces there was at least 81·54 per cent. of valuable fuel lost; and, as about fourteen tons of coal were used every twenty-four hours, it followed that 11·4 tons of coal were lost, by escaping at the mouth of the furnace in the form of gas capable of being used as excellent fuel. It was also proved, that by the combustion of these gases, a temperature could be obtained equal to what would melt iron.

After the application of the hot-blast to the furnace, several manufacturers tried to heat the air or blast by the waste heat of the furnace; adopting several methods of causing the air of the blast to pass through pipes ranged around the trunnel head, or coiled round the interior of the furnace so as to be heated by the ignited materials themselves, or built into the masonry so as to receive heat by transmission: these plans were, after various trials, abandoned. Other expedients were adopted, such as covering the top of the blast furnace, except during charging, and carrying the gases to a reservoir or gasometer, from which they were pumped into a gas furnace for heating the blast; but from several practical difficulties these plans also were abandoned.

In 1848 Mr. Palmer Budd adopted a more successful mode of applying the waste heat of the blast furnace; part of his success lay in not making his apparatus a portion of the furnace, nor burning the gases; hence the operations did not interfere in any way with those of the blast furnace. Three or four horizontal flues, of about twelve inches diameter, are constructed about three feet below the top of the furnace, and lead into an adjoining chamber or stove provided with a stalk, which creates the draught. Into this stove he draws as much of the gaseous escape as he requires, the supply being regulated by means of a damper. The quantity required to heat the blast for a furnace, he considers to be only about one-sixth of that which passes off from the trunnel head. He does not burn the gases, but allows them to pass hot through the stove or furnace for heating the blast; they enter at a temperature of about 1800° Fahr., and leave it at a temperature of about 800°, the heat required for the blast being about 600°; and thus the mere passage of these heated gases through the stove serves his purpose.

Mr. Budd says that his plan has several great advantages; it requires no coal or labor, the blast is better and more regularly heated, and the apparatus more durable. Besides the heating of the blast, the same ingenious manufacturer applied these heated gases to his steam-boilers, and states that the saving effected by the application to one boiler was equal to three hundred and fifty pounds sterling per year, and the total saving in his works by doing away with the use of coal in all the boilers, fire-bars, *et cetera*, would at full worth exceed two thousand pounds sterling *per annum*.

Notwithstanding these practical results, the improvements recommended have not been generally adopted. TRURAN, while acknowledging that the gases escaping from certain blast furnaces, may, with proper management, be made to yield eighty-two per cent. of the caloric evolved during the imperfect combustion of the fuel, dissents from the generally-received opinion, that a sufficiently intense heat can be maintained by their combustion for the purposes of the forge, or for the rapid generation of steam. Although the actual heat evolved be ample for generating steam and for heating the blast, still, owing to its dissemination through such a large volume of gas, the quantity of heat in contact with the plate-iron is small, and the evaporating power is much slower than with coal fires.

At three several experiments made at the Dowlais Works, the temperature obtained rarely went above a dull red heat, and the evaporating power of the boiler, as compared with a coal fire, was reduced nearly two-thirds. At the Ebbu Vale, Aberychan, Sirhowy, Aberdare, Ystalyfera, and other establishments using the gas, the number of boilers now in use is nearly twice as many as formerly sufficed with coal fires only.

After a careful examination of the various modes of collecting the gases adopted in this country and on the Continent, and having witnessed the alterations produced on the operations of the blast furnace by each, TRURAN gives it as his opinion that it is neither expedient nor profitable to control the escape of the gases; and that where the consumption of coal is proportioned to the requirements of the case, not one particle of gas, or one unit of heat, can be withdrawn from a furnace, without disturbing the equilibrium of the smelting. This opinion is at variance with the statements of Continental chemists, but it must be remembered that their estimates of the commercial value of the products of combustion have invariably been drawn from theoretical calculations, and are based on the assumption that they may be withdrawn in quantity without affecting the smelting. But the fact of their withdrawal occasioning an alteration in the economy of the furnace, has been established in practice; and, on the whole, the brilliant anticipations formed of the value of these gases for heating purposes have not been realized. The obtaining of the iron being the primary object in all the operations of the blast furnace, whatever improvements or alterations are made must in no way interfere with either the quality or quantity of the metal produced, and every alteration affecting this must be adopted with great caution. At the same time, the practical observations above-mentioned are of the highest importance, and should stimulate to further inquiry.

STATE OF THE BLAST.—In connection with the gases evolved in the working of the blast furnace, this may be the proper place to consider the state of the blast as it is allowed to enter into the furnace. It has been seen from the analyses of the gases passing through the furnace, that, however great the quantity of air admitted, it was all consumed, no oxygen passing through uncombined; but it has likewise been shown that it is not all profitably consumed, which is a desideratum. There is a general opinion amongst practical men, that the furnace works best and produces the largest casts, and frequently the best iron, in dry frosty weather, and the opposite when the weather is warm and moist. The irregularity of the working of the furnace from these supposed causes, led Mr. JOHN HART, a few years ago, to institute a series of experiments upon this subject. He ascribes some of the irregularities to differences in the atmospheric pressure; thus the range of the barometer in this country being about three inches, or rather more than one-tenth of the mean pressure, this change of density would produce a difference of one-tenth in the bulk of the air; and, therefore, between a severe frost with the thermometer at 20°, and sultry weather with the thermometer at 70°, the difference would be 50°; and as atmospheric air dilates or contracts one four hundred and eighty-fifth part for every degree, this difference in temperature would produce a variation of rather more than one-tenth in the mass or bulk of the air; so that, if during severe frost the barometer stood at thirty-one inches, while during sultry weather it stood at twenty-eight inches, the combined effects of the difference in temperature and pressure would amount to a total variation of one-fifth in the bulk of the blast, which would be nearly equivalent to a careless furnaceman putting into his furnace ninety pounds of coal instead of one hundred, during a whole casting. Indeed, the difference from temperature and pressure amounts to something like an irregular charging of the furnace with ninety pounds up to one hundred and twelve pounds indiscriminately, instead of one hundred pounds regularly.

There is still another source of irregularity, occasioned also by the barometric changes in the density of the air, when the power employed is the double-stroke condensing steam-engine having neither fly-wheel nor governor to regulate its speed, and whose motion is only contracted by the resistance of the blast. As the fireman keeps up his steam to the regular pressure indicated by the steam gauge, without any reference to the pressure of the air, whether it can support twenty-eight or thirty-one inches of mercury; and as the steam must always displace the atmosphere, to make room for itself: therefore the difference of pressure upon the steam-loaded piston descending into a vacuum, will be one-tenth greater when the mercury is at thirty-one than at twenty-eight inches; hence, if a blowing engine works to forty horse-power, when the barometer is at twenty-eight inches, it will work equal to a forty-four horse-power when the mercury is at thirty-one inches, and of course it will perform an additional number of strokes. However, these atmospheric changes being comparatively slow, will affect the quantity more than the quality of the iron.—*Hart.*

These observations of Mr. HART are certainly worthy of attention; the impression of the effect of moisture in the air is still as firmly held as ever. Taking the average of five years, selected at intervals of the same period, for twenty-two years' working, the following quantities of coal were consumed for every ton of crude iron produced :—

	Winter. Cwt.	Spring. Cwt.	Summer. Cwt.	Autumn. Cwt.
Foundry iron furnace,	49·7	52·2	53·1	55·4
Forge iron furnace,	43·6	44·2	44·6	45·8
Blast iron furnace,	43·2	44·1	50·1	49·5

In the first or foundry furnace, the excess of autumn over winter months is eleven per cent.; in the forge furnace equal to five per cent., and in the blast fifteen per cent.

How useful would a series of meteorological observations have been in connection with these results!

Advantages of the Hot-Blast.—The great practical discovery in connection with the blast furnace, and one which has formed an era in the iron trade, is the introduction of the *hot*-blast, which is now all but universally used by the iron smelters in this and other countries. The advantages of hot-blast are, an increased make of iron, and great economy in the consumpt of fuel. These advantages, however, are not equal in all localities, nor with all classes of ore and coals; in general, greater benefit has been experienced in Scotch than in English furnaces, either owing to the former having been working less economically than the latter, previous to the introduction of the hot-blast—thus making the saving appear greater; or else the fuel used in Scotch furnaces being in general weaker than the English, the hot-blast has consequently effected much greater comparative advantages. So early as July, 1833, a comparison of the product of the blast furnaces in the neighborhood of Glasgow, before and after the introduction of the hot-blast, gave the following results :—

By cold-blast—

	Tons.	Cwt	lbs
Consumed for each ton of iron, three tons coke, equal to,	6	13	0
For the blowing engine,	1	0	7
	7	13	7

using ten and a half hundredweight of limestone.

By hot-blast—

	Tons.	Cwt.	lbs.
Consumed for each ton of iron, raw coal,	2	0	0
For heating the air,	0	8	0
For blowing engine,	0	11	2
	2	19	2

using seven hundredweight of limestone.

The economy in fuel is proportional to the temperature of the air admitted into the furnace. This saving of fuel was accompanied by an increased make of iron of upwards of one-third, which adds materially to the advantage of using hot air.

How these effects are produced, is a question which has not yet been answered to the general satisfaction of scientific men. The opinion of the chemist may be stated thus:—Wherever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. There is nearly equal temperature over the whole extent of a fire-place; so that if the air and coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to prevent the resulting temperature from rising to a proper pitch; but if they were very hot, they would absorb less caloric, and would leave more to elevate the general temperature. This excess of temperature may produce in metallurgical operations, *a play of affinities dormant at lower degrees of heat;* often a few degrees is all that is required to modify the state of a fusible body.

THE SLAGS.—Having entered at considerable length upon the gaseous products, the state of the blast, and the theory of the action, both mechanical and chemical, that takes place within the furnace, it will now be necessary to advert to the fluid or solid products; namely, the slag or scoria, and the metal. The intrinsic value of the former is nothing to the ironmaster: the great end of all the operations is the iron; but the appearance and quality of the slag is an index to the working condition of the furnace, and the quality of the iron. The furnace-manager must therefore keep a watchful eye on the state of his slags, when withdrawn from time to time. If the furnace is yielding an iron proper for casting into moulds, the slags have a uniform vitrification, and are slightly translucid. If the quantity of ore be too much in proportion to the other matters—an excess which is sometimes intentionally introduced, in order to produce a grey pig-iron fit for fabrication into bars—the slag is opaque, dull, and of a greenish-yellow tint, with blue enamelled zones. When the furnace is producing a white metal, which is an inferior quality, the slags are black, glassy, full of bubbles, and emit an odor of sulphide of hydrogen. Such are the three leading characteristics of the quality of the slags; but practice can detect the slightest tendency towards any of these conditions, so that much depends upon a careful furnace-manager.

The quality of the slag becomes, therefore, an important consideration to the smelter, as anything that will affect the obtaining of a good slag, any want of material in its composition, will affect the quality and quantity of the iron; nevertheless, the principle of good slags does not appear to depend so much on any particular composition, as on the obtaining of a slag that is perfectly fusible, and capable of taking up from the ore all the earthy matters. The appended analyses will show this :—

	I.	II.	III.	IV.	V.
Silica,	43·75	38·12	40·4	36·6	55·48
Alumina,	12·50	16·97	11·2	37·5	19·32
Lime,	31·22	32·77	38·4	20·7	14·57
Magnesia,	17·15	6·22	5·2	1·5	2·54
Protoxide of manganese and iron,	4·88	5·92	3·8	1·0	4·36
Sulphur,	—	—	—	2·7	2·43
Loss,	·50	—	1·0	—	1·30
	100·00	100·00	100·00	100·00	100·00

The first three are good slag, giving good iron; the fourth was not considered so by the workman, and led to a change in the proportion of materials, producing a white iron; the fifth is a bad slag, both in color and structure, yielding an inferior quality of iron of the following composition:—Iron, 88·9; carbon, 3·0 silicious matters, 7·4; sulphur, ·7. The subjoined table of analyses of slags from the blast furnace, is from the report made upon that subject to the British Association by Drs. PERCY and HENRY:—

Silica,	38·05	38·76	37·63	37·91	39·52	28·32	45·59	52·31
Alumina,	14·11	14·48	12·78	13·01	15·11	24·24	11·88	5·12
Lime,	35·70	35·68	33·46	31·43	32·52	40·12	38·20	30·71
Magnesia,	7·61	6·84	6·64	7·24	3·49	2·79	—	9·50
Manganese,	·40	0·23	2·64	2·79	2·89	0·07	0·91	1·41
Protoxide of iron,	1·27	1·18	3·91	0·93	2·02	0·27	1·11	0·95
Potassa,	1·85	1·11	1·92	2·60	1·06	0·64	—	—
Sulphide of calcium,	·82	·98	·68	3·65	2·15	3·64	1·76	—
Loss, *et cetera*,	·19	·74	·34	·44	1·24	0·09	0·55	—
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Phosphorus, which is a common ingredient in iron ores, and is considered to be very prejudicial to the metal produced, has been carefully sought for in the slags, and various means have been tried of causing it to combine with these in preference to the metal. Ores containing phosphorus, which may be distinguished as Nos. 1 and 2, were smelted with hot and cold blast, and the iron and slag tested for phosphorus gave the following results:—

By hot-blast the iron, No. 1, contained 0·74; No. 2, only 0·68 per cent. phosphorus, and the slag only a trace. By cold-blast the iron, No. 1, contained 0·81; No. 2, only 0·62 phosphorus, and the slag only a trace. The conclusions derived from a series of experiments were, that ordinary iron, such as the bands and hematites, whether smelted by hot or cold blast, will give the phosphorus in the iron with grey pig-iron; but if white iron is produced, and the slag contain protoxide of iron, some of the phosphorus may go away in the slag. For example, samples of slag from white iron made from pisolitic ores, gave—

Silica,	41·11	37·84
Alumina,	13·45	13·20
Lime,	29·82	20·68
Protoxide of iron,	6·44	20·83
Magnesia,	4·75	2·93
Protoxide of manganese,	0·66	0·80
Alkalis,	1·84	1·08
Phosphoric acid,	0·15	1·77
Sulphide of calcium,	1·34	0·87
Loss,	0·44	0·05
	100·00	100·00

This slag was considered bad by the workmen.

Various patents have been taken for the application of slags to useful purposes, especially to building. The difficulty in the annealing and in producing a compound from these slags not capable of being affected by the air, combined with the cheapness of the articles for which it is to be used as a substitute, will operate greatly against the profitable and general application of such substances; still, the Editor would not wish to discourage the prosecution of any scheme for utilizing waste products of manufacture, as he considers this subject too much overlooked by manufacturers generally.

THE METAL.—The next and most important product of the blast furnace is the iron. It has been seen that this, unlike other metals, which must be pure before they can be available for useful purposes, is practically valuable in various states of impurity, or, perhaps it may be better to say, in various states of combination. Pure iron is tough, malleable, and ductile; is softened into a sort of clayey or pasty consistence by intense heat, but is not melted. In combination with carbon, it assumes various degrees of hardness, tenacity, *et cetera*, according to the quantity of that element in combination with it; but besides the carbon, there are also other impurities affecting the quality of the iron, as silica, phosphorus, manganese, and other matters found in the ore, fuel, and flux. According to the appearance it presents in fracture, it is divided into different qualities, as under:—

No. 1.—Grey or black and soft—best quality of cast-iron.
No. 2.—Mottled—a mixture of No. 1 with No. 3.
No. 3.—White—an inferior iron for certain purposes.
No. 4.—Silver iron—a still inferior quality.

From the mere analysis of cast-iron, it is very difficult, if not impossible, to discriminate the line where grey ceases and white begins, *et cetera*. The subjoined are a few of the results obtained by analyses, showing the effect of different kinds of fuel:—

IRON SMELTED WITH CHARCOAL.

Iron,	96·77	96·2	96·8	96·0	95·3	95·9	96·0
Carbon,	2·95	3·5	3·1	3·6	4·2	3·6	3·5
Silica,	0·28	0·3	0·1	0·4	0·5	0·5	0·5
	100·00	100·0	100·0	100·0	100·0	100·00	100·0

IRON SMELTED WITH COKE.

Iron,	92·5	92·2	94·2	95·3	97·8	98·8
Carbon,	3·0	4·3	2·3	2·2	1·7	1·0
Silica,	4·5	3·5	3·5	2·5	·5	·2
	100·0	100·0	100·0	100·0	100·0	100·0

The preceding analyses were mostly made on the Continent in different localities.

GREY PIG-IRON SMELTED IN WALES WITH COKE.

Iron,	95·15	95·81	94·84
Carbon,	2·45	2·55	1·67
Silica,	1·62	1·20	3·00
Phosphorus,	·78	·44	·49
Manganese,	trace.	trace.	trace.
	100·00	100·00	100·00

IRON SMELTED WITH COAL—SCOTLAND.

Iron,	93·6	93·4	92·3	89·7	91·6	94·2
Carbon free,	1·4	·5	1·8	2·5	1·5	1·6
Carbon combined,	1·2	1·9	·4	·7	·3	·5
Silica,	1·5	1·2	2·8	2·2	1·8	1·1
Sulphur,	·4	1·4	1·4	—	·6	—
Phosphorus,	·4	1·2	1·3	—	·9	—
Manganese,	·5	·4	—	2·8	2·6	1·5
Slag,	1·0	—	—	2·1	·6	1·1
Loss,	—	—	—	—	·1	—
	100·0	100·0	100·0	100·0	100·0	100·0

The introduction and extension of the hot-blast led to a good deal of valuable investigation, both as to the chemical and mechanical qualities of the iron so produced; and the subject is yet far from being exhausted. The chemical question has been, whether that produced by the hot or by the cold blast is the purest, and what impurity prevails? The following analyses of the two products—cold and hot blast—will give a general view of the result with certain kinds of ore. The experiments were made at the Hartz :—

	Cold-blast.		Hot-blast.	
	Specific gravity, 7·43.	Specific gravity. 7·08.	Specific gravity, 7 166.	Specific gravity, 7 077.
Iron,	93·29	93·66	91·42	91·98
Carbon combined,	2·78	0·48	1·44	0·95
Carbon free,	1·99	3·85	2·71	3·48
Phosphorus,	1·23	1·22	1·22	1·68
Sulphur,	trace	trace	trace	trace
Lime,	trace	—	trace	—
Silica,	0·71	0·79	3·21	1·99
Manganese,	trace	trace	trace	trace
	100·00	100·00	100·00	100·00

From these analyses it appears that the hot-blast iron has more silica than the cold-blast.

The annexed analyses, however, made by Dr. THOMSON and Mr. J. TENNANT, prove that the question must be further studied in relation to many circumstances not yet taken into consideration :—

	Cold-blast. Specific gravity 6·70.	Hot-blast. Specific gravity [illegible]
Iron,	91·95	95·58
Manganese,	2·03	·83
Carbon,	3·85	2·09
Silica,	1·17	1·68
Alumina,	1·65	·42
Loss,	·15	—
	100·00	100·00

The mechanical constitution of the two products does not come so directly under the consideration of the chemist. The Editor will, therefore, merely give the results of some experiments which were laid before the British Association a few years ago. In the following table, the second column shows the force in pounds necessary to crush a cylinder, the transverse section of which is a square inch; the third column gives the force in pounds, which is required to tear asunder the same cylinder; and the ratios of these forces are shown in the fourth column :—

Description of metal.		Compressive force per square inch in pounds.	Tensile force per square inch in pounds.	Ratio
Devon iron,	No. 3—hot-blast,	145,435	21,907	6·638 to 1
Buffery iron,	No. 1—hot-blast,	86,397	13.434	6·431 to 1
" "	No. 1—cold-blast,	93,385	17,466	5·346 to 1
Coed Talon iron,	No. 2—hot-blast,	82,734	16,676	4·961 to 1
" "	No. 2—cold-blast,	81,770	18.955	4·337 to 1
Carron iron,	No. 2—hot-blast,	108,510	13,505	8·037 to 1
" "	No. 2—cold-blast,	108,375	16.684	6·376 to 1
" "	No. 3—hot-blast,	133,440	17,755	7·515 to 1
" "	No. 3—cold blast,	115,442	14,200	8·129 to 1

From this table it appears that the resistance of cast-iron to rupture by extension varies from six to nine tons upon the square inch; while its resistance to compression varies from thirty-six to sixty-five tons. It further appears that the absolute strength of some kinds of iron, both as regards their tenacity and their power of resisting compression, is considerably increased by the hot-blast.

Owing to the very infusibility of pure iron, it would be impossible to obtain it in large quantities, were it not for what may be termed its impurities, especially its combination with carbon. In this form it is easily fused, and, by processes afterwards to be described, the pure or malleable iron may be separated from the carbon which has served the purpose of extracting it from the ore and oxygen.

FOUNDING.—A great quantity of the iron produced by the blast furnaces is used in the state of cast-iron for a variety of purposes in the arts and manufactures. The qualities employed for this purpose are termed foundry-iron, and include the grey and mottled pig-iron, these kinds being more easily fused than the white, which is known as forge-iron. The founder divides cast-iron into five classes:—

No. 1 is the best grey; it possesses the greatest quantity of carbon, and melts at a lower degree of heat than any of the others; it sets with a smooth surface, is soft, and has little sound when struck by the hammer.

No. 2 is lighter in the color than number one; not so soft nor so fluid when melted, nor so smooth on the surface when solidified; it is closer in the texture, and is preferable for strong parts of machinery.

No. 3 has less carbon than the other two, and is still less fluid when melted; has smaller grains, and is smoother in the fracture. This is used for very strong machinery where it is subjected to sudden and great strains, such as heavy shafts, wheels, *et cetera.*

No. 4 is not so much employed for foundry work; it is lighter in color, harder, and is sometimes employed for foundry work; it requires some experience to distinguish it from number three, and this can only be done comparatively.

No. 5, or what is termed white-iron—sometimes silver-iron—is very seldom used in the foundry; it is very brittle, and does not run into the moulds, being difficult to keep in fusion.

The distinguishing of these qualities is more dependent upon practical experience than any theoretical description of quality. The following practical directions are given by Grier:—

When cast-iron is fractured, it exhibits a grey color, sometimes approaching to dull-white, and, in other cases, to dark-grey, with spots nearly black. The lustre is sometimes metallic, resembling freshly-cut particles of lead lying on the surface; and, in other cases, there seems to be crystals in the iron disposed in rays.

When the color is a uniform dark-grey, the iron is tough, provided there be also metallic lustre; but if there be no metallic lustre, the iron, though soft, will be more easily crumbled than in the former case. The weakest sort of soft cast-iron is where the fracture is of a dark hue, mottled, and does not shine.

The iron may be accounted hard, tenacious, and stiff, when the color of the fracture is lightish-grey with a high metallic lustre.

When the tint is light-grey, without metallic lustre, the iron is hard and brittle.

If the hue is dull-white, the iron is more hard and brittle than in the last case.

When the fracture is greyish-white, interspersed with small radiating crystals, the iron is of the extreme degree of hardness and brittleness.

The best way to try the quality of cast-iron is to strike its edge with a hammer. Should the blow make a slight impression, the iron must be in some degree malleable, and, if the specimen be uniform, it may be regarded as good for machinery; if, on the contrary, the hammer make no impression, and fragments fly off, the iron is brittle, and, consequently, bad. The soft cast-iron yields readily to the file after the outer crust has been removed, and is, in a cold state, slightly malleable.

The quality is also easily judged when in the melted state from the nature of the agitated aspect of its surface. The mass of fluid seems to undergo rapid circulation within itself, inducing a constant tremor on the surface, having the appearance of ever-varying net-work; when this net-work is minutely subdivided it indicates soft iron. If, on the contrary, the iron be thrown up in large convolutions, the quality of the metal must be hard.

In founding, it is necessary to select the class of iron most suitable for the kind of articles to be cast. The furnaces used in this operation are termed cupola furnaces. These are also of various construction, and are generally urged by a blast similar to that employed for the smelting furnace, or, what is more common in foundries, by a fan-blast. Fig. 295 is a front elevation of an ordinary cupola of a large size; Fig. 296 is a vertical section in a plane at right angles to that of Fig. 295; *a* is the charging door, about two feet square, by which the pig-iron and coke are introduced into the furnace; *b* is the tapping-hole, fifteen inches square, at which the melted metal is occasionally drawn from the furnace; *c e*, not seen in Fig. 295, are the tuyere holes or orifices by which the blast enters, to afford a supply of air capable of maintaining a sufficiently intense heat in the furnace by combination with the fuel. These apertures are of considerable extent upwards, so as to admit of the tuyeres being set to any height required, which is regulated by the quantity of metal that may be collected in the furnace; for, of course, the tuyeres must always deliver their air clear of the surface of the metal. The tuyeres are knee-pipes for delivering the blast into the cupola, into which one end is directed, while the other extremity slides in an upright pipe through which the blast is con-

Fig. 295.

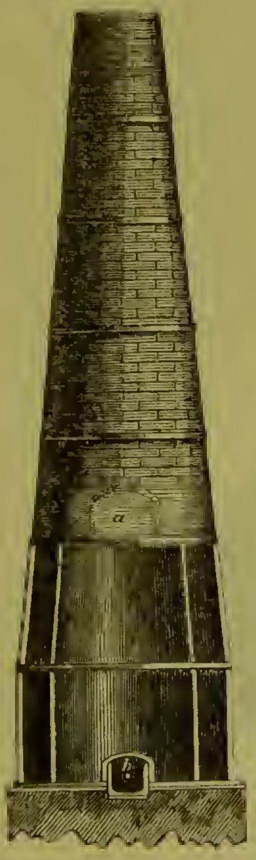
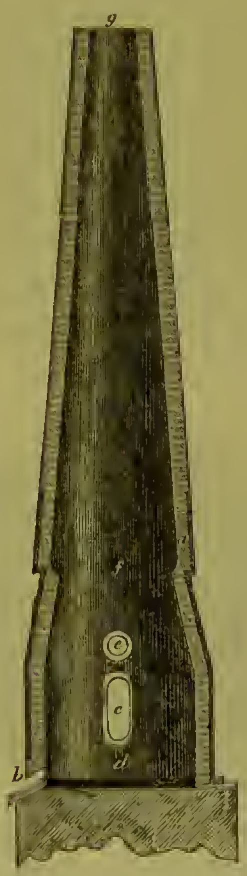


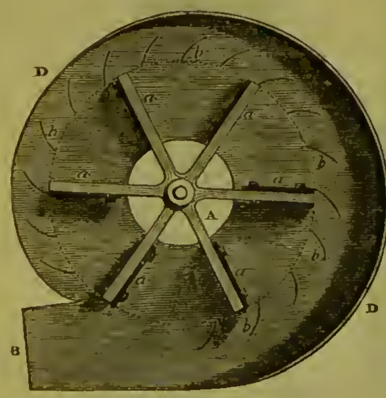
Fig. 296.



veyed, in the manner of a telescope-tube, so that the tuyere may be set to any height required. The under part, *df*, of the structure below the charging door, is the most essential division, and is indeed that which gives its character to the furnace. The upper portion, *fg*, is the chimney, intended to convey away the volatile noxious products of the whole operation of fusion, being sufficiently long to pass out through the roof of the foundry. The furnace is built entirely of fire-brick, and it will be observed that the trunk is incased in cast-iron plates bolted together. The casing is in some instances cast in one or two entire cylindrical pieces, and in other instances it is made of boiler plates rivetted together. The latter is undoubtedly the more durable material, as it stands the alternate expansion and contraction with much less injury to itself. The chimney is simply bound with wrought-iron belts fastened round it at regular intervals. The whole structure stands upon a square base-plate, of which the centre is cut out into a circular aperture; this plate is bedded upon a brick or stone foundation, represented in the figures. As the bottom must be protected from the action of the melted metal which collects there, it is laid over with a bed of sand, mixed with wet loam to give it consistency. This is shown in section at *d*, Fig. 296. It is continued over the bottom and sides of the spout, *b*.

Fig. 297 represents the most approved form of fan for producing the blast. It consists of a central spindle, upon which are hung six arms, *a a*, meeting on an eye at the centre, through which the axle is passed, and by which they are fixed to the axle. Upon each of these arms a square blade, generally of sheet-iron, is firmly fixed by rivets or bolts, and these blades constitute the propelling agents. To render them effectual, they are incased in a round box, D D, having a central opening, A, on each side for the admission of air, and an opening, B, in the circumference, with a short prolongation, for the expulsion of the air. By the rapid revolution of the blades, a strong current of air sets in at the centre, and to prevent it from impinging against the cover, D, by which its progress would be retarded, a series of cutters, *b b*, are fixed between the cheeks around the dotted circle, which indicates the line described by the outer edges of the revolving blades. These cutters are curved, and are so placed that they may receive the air on their interior edges in the tangents to their curvatures, by which precaution the air should glide uninterruptedly upon their interior surfaces, and ought to be deflected in the direction of its motion, so as to join smoothly in with the general current which is propelled through B, to the tuyeres leading into the cupola.

Fig. 297.



According to experience, the iron melted in a cupola urged by a fan-blast improves more in the operation of melting than when a cylinder-blast is used, although the latter has certain advantages which the practical man considers important.

The fires in the cupola furnaces are generally kindled by putting in a quantity of wood, which is then ignited; the usual fuel, either coal or coke, is afterwards introduced, and the blast applied. When a sufficient heat is raised, and the cupola is well filled with fuel, quantities of pig-iron are thrown in, which melts in its passage down, and finds its way to the bottom or hearth in the same way as in the blast furnace. If the fuel be of good quality, having little earthy matter in it and no sulphur, the iron during this melting is considerably purified; a portion of the iron and silica in the pigs is oxidised, forming silicate of iron, which, from its less specific gravity, floats upon the surface of the metal, and is separated as scoria or slag; the remaining charge of iron is consequently much purer and makes a stronger metal. When the fuel contains earthy matter, this combines with a portion of the iron, also forming silicate and scoria, by which means much of the metal may be lost without in any way tending to purify what remains. It is, therefore, a common custom to put into the furnace a small portion of lime, which acts as a flux upon the silica of the coal by which the iron is partially saved. Coke, which is seldom free from sulphur, is very generally used as fuel. —See analysis of coke, article FUEL.—The sulphur has a strong tendency to combine with the iron, and often to an extent sufficient to deteriorate greatly the quality of the metal in the cast, as the sulphide diffuses itself through the body of the iron. From analyses made of pig-iron before and after being fused in the cupola by certain qualities of coke, it was found to give in the former case only 0·4 per cent. of sulphur; and in the latter so much as 1·0 per cent., showing an increase of six-tenths of a per cent. derived from the fuel. The quality of the fuel for cupola furnaces should, therefore, be a primary consideration with the iron founder. Wood charcoal, being free from sulphur, is employed with advantage where it can be had in abundance.

MANUFACTURE OF MALLEABLE IRON.—When pig-iron is to be converted into malleable or bar-iron, it has to undergo certain processes of purification, to separate the metal from the foreign matters which more or less affect its natural properties of malleability and ductility. Athough these foreign matters were essential to give it the necessary fusibility for the obtaining of the cast-iron from the ore, and are, for the same reason, equally essential for the production of cast articles so valuable in machinery and other works of art, they must be got rid of in that iron which is to be used for purposes requiring the greater tenacity and strength of the pure material. The operations of refining consist in remelting and blowing upon the iron, to burn out a portion of its impurities, and then subjecting it to a process of heating and hammering, termed *puddling*, by which means, partly chemical and partly mechanical, the foreign matters are eliminated from the metal.

Refining.—The first operation, or that more generally termed *refining*, is performed in peculiarly-constructed furnaces, called *refineries* or *running-out fires*. These are composed of a body of brick-work, about nine feet square, rising but little above the ground, and are shown in Figs. 298 and 299, the former of which is a sectional elevation and the latter a plan. The hearth, H, is placed in the middle of this, and is of a rectangular shape, being about three feet by two, and about thirty inches deep; it is formed by the junction of four cast-iron troughs, A, through which a stream of cold water is made to circulate to prevent them from being fused by the heat. Over the hearth, and supported by iron columns, B, about six feet high, is a chimney from ten to twelve feet high, making the total height about twenty feet. The tuyeres, *f*, are placed on the longest sides of the hearth at the lip or edge, and are inclined towards the bottom so as to blow upon the bath of melted metal. The noze-pipe is incased similarly to that of the blast furnace, and water is made to circulate in the hollow space by cylindrical tubes, to prevent the tuyeres from being burned. The supply of water for this purpose is brought by the pipe, *a*, into the reservoirs, *b*, from which it flows through the pipes, *d*, to the nozzles of the tuyeres, and thence escapes by the tubes, *c′*, into the tanks, F; from these it is conveyed by the siphon-tubes, *c*, into the troughs, A. The blast arrives at the tuyeres through the mains, E, which are furnished with screw-valves at *c* for the purpose of regulating the supply. The tapping-hole, O, is placed at one of the shorter sides of the hearth, and by it the melted metal and the slag flow out into the mould, M.

Fig. 298.

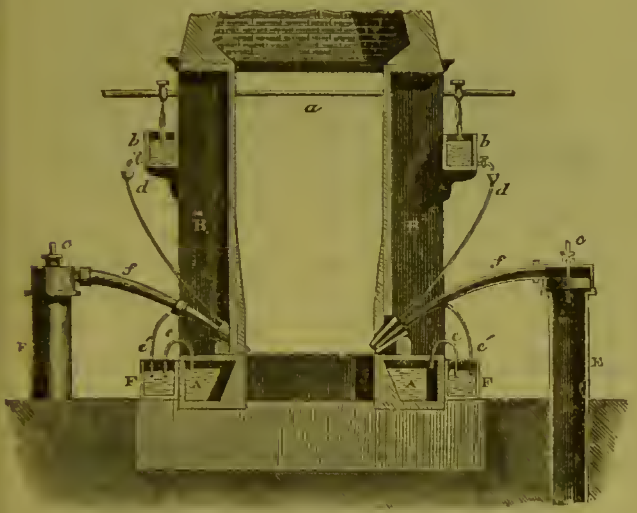
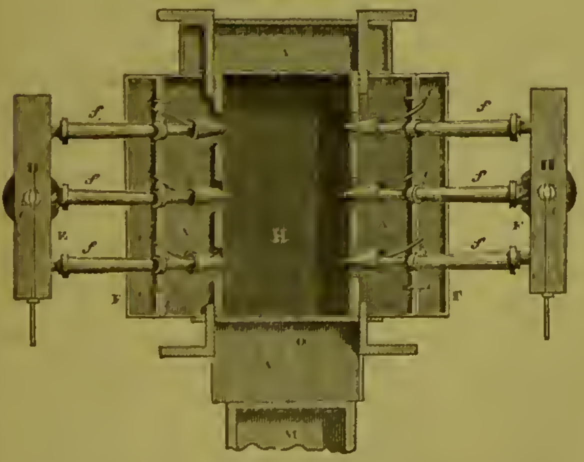


Fig. 299.



The operation begins by filling the hearth or crucible portion of the furnace with coke; upon this are laid six pigs of iron from the blast furnace, and more coke is heaped upon them. The fire is kindled at bottom; after a little the blast is let on, and, as the heat increases, the iron melts and flows to the bottom; more coke is added as it burns away, to preserve the metal in a state of fusion. The iron during this operation expands, heaves up, and evolves oxide of carbon. After about two hours the metal is tapped out into pits or beds, forming large plates, upon which quantities of water are thrown with the view of rendering it brittle. The metal thus treated is very white, and possesses in general a fibrous radiated texture, consequent on its rapid cooling; it is also full of cells from the escaping of gaseous matters. In this operation there is formed a heavy black scoria, principally composed of silicate of iron with other impurities. When the iron is very inferior in quality, a small portion of lime is added to the fire to take up the earthy matters; in this case the scoria will contain lime. As already remarked, in fusing iron in the cupola the earthy matter in the coke employed requires a little lime to combine with it; otherwise, if present in any considerable quantity, it will take away much of the iron. In some places the iron is run into these refining furnaces directly from the blast furnace, a method which saves the time and fuel required to remelt the pigs; but this saving is attended with certain disadvantages which have prevented its general adoption.

The change effected upon the iron in this operation is the oxidation and consequent separation of a great portion of the impurities. The following are analyses of the results:—

	Iron from blast before refining.	Same iron after being refined.
Iron,	95·26	98.33
Carbon,	2·63	·87
Silicium,	1·38	·53
Aluminium,	·73	·26
Phosphorus,	trace	trace
Sulphur,	trace	trace
	100·00	99·99

The slag or scoria from the refining of the above iron gave—

Protoxide of iron,	70·3
Silica,	21·5
Alumina,	7·8
	99·6

As a general rule, the longer the blowing and consequent exposure to the oxygen of the blast, the greater the deprivation of alloys and improvement in quality; but the process may be unnecessarily prolonged.—*Truran.*

A very good criterion of the effect produced upon the iron by this process, is the composition of the cinder or slag from the operation. BERTHIER gives the following analyses of this slag from two different works in different localities:—

	Dudley.	Dowlais.	
Protoxide of iron,	61·2	61·0	52·0
Silica,	27·6	36·8	42·4
Alumina,	4·0	1·5	3·3
Phosphoric acid,	7·2	—	—
	100·0	99·3	97·7

The presence of the phosphoric acid in the scoria is important, as showing the use of the operation; a portion of both the silica and alumina may have been in the ashes of the fuel, so that this should be strictly attended to in these investigations. The following is an analysis of refining cinder from a work near Birmingham:—

Protoxide of iron,	61·28
Silica,	22·76
Protoxide of manganese,	3·58
Alumina,	7·30
Lime,	3·41
Magnesia,	·76
Sulphur,	·46
Loss,	·45
	100·00

It is very probable that several of these matters have been from the fuel. If the fuel contains much silica, the loss in iron, from this cause alone, will be considerable. In the above analysis the silica and protoxide of iron appear as one to three. The combined weight of the iron and cinder is always more than the weight of the pig-iron put in. Truran gives, as the result of his own experience, the following:—

			Pounds.
Crude iron put in,			2498
Produce,	Refined metal,	2240	
	Cinder,	325	
			2567
Showing an excess of weight,			69

The principal portion of the excess, says this authority, is due to the fixation of oxygen forming the protoxide of iron in the cinder, silica, and alumina. The remaining portion is composed of the siliçious earths of the coke and stones composing the hearth. The increase of weight by the oxygen in the scoria is counterbalanced by the direct loss of carbon; so that the increase is wholly from the last-named sources, the ash of the fuel and stones of the hearth. The loss of iron in this process varies according to the quality of the crude iron. Berthier gave from his results twelve to seventeen per cent. of loss; in the preceding statement of Truran tho loss is ten per cent.

Puddling.—The next process of refining is termed *puddling*, and is performed in a reverberatory furnace of the shape shown in sectional elevation and plan in Figs. 300 and 301. The sole or hearth, D, is made of brick or cast-iron; if of the former, it is arched below, the bottom of the furnace being the top of the arch; if of the latter, it is a large plate of cast-iron, supported by pillars, and is covered with a layer of slag, which is made to incline towards E, where there is a rapid fall to allow of the escape of the slags formed during the process; these are removed at the opening or *floss-hole*, *b*. The length of the hearth is about six feet; its breadth at the middle about four feet; at the chimney-end about two feet; and from two and a half to three feet at the fire-end. The fire, A, i separated from the hearth by a wall of fire brick, *a*, about ten inches high, termed the bridge. The draught is produced by a chimney, F, forty or fifty feet high and furnished at top with a damper, H, which ca be raised or lowered by means of a chain and lever.

Fig. 300.

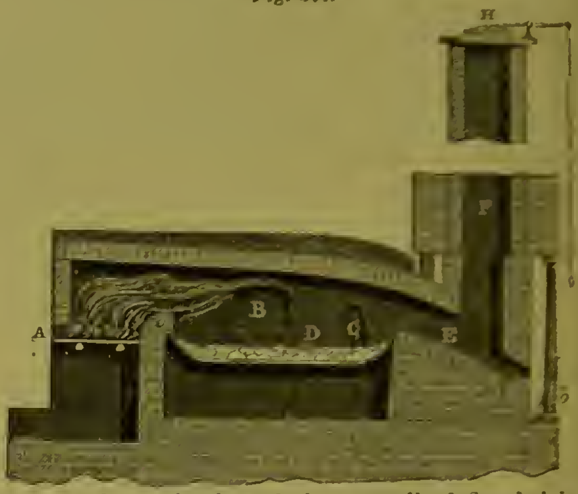
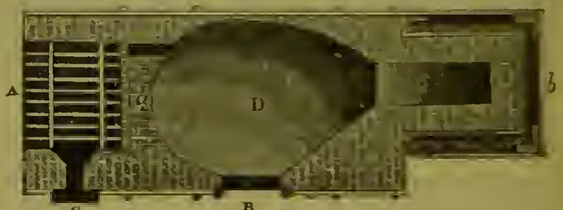


Fig. 301.



The opening, C, which communicates with the grate, is generally closed by heaping up the fuel. The opening, B, into the hearth or sole of the furnace, is that through which the workman introduces his iron bar, or *paddle*, during the process of puddling. Nearer the chimney is another aperture, G, which is used for cleaning out the furnace at the end of an operation.

From three and a half to four hundredweight of the fine metal obtained by the refining process is put into the puddling furnace, in pieces laid one upon another upon the sides of the hearth, leaving the centre or middle part free for the operations of the puddler. The furnace is then closed up, and the fire pushed to a high heat; in about twenty minutes the metal begins to melt, and falls off in drops upon the sole of the furnace. The furnaceman, by means of a paddle, removes the iron from the hottest parts to prevent its melting too rapidly. When the whole of the metal is reduced to a pasty state, the temperature of the furnace is lowered that it may not become more fluid. The furnaceman then works about the pasty metal with his paddle, during which it swells up with the discharge of gaseous matters. As this goes on, the metal becomes less fusible as it gets finer, the gases cease to escape, and by the constant puddling or kneading with the paddle, it becomes reduced to a sort of sandy consistence. During these operations, small quantities of water are thrown into the furnace. At this stage the heat is increased, and the particles of metal begin again to agglutinate, and become, in the language of the workman, *heavy*. The furnaceman with his paddle gathers a lump of metal on the end of it, as a nucleus, and makes it roll about on the surface of the clotted mass; he thus collects a ball of about seventy pounds in weight, which is placed on the side of the hearth at the hottest part, where, with a rake or paddle, termed a *dolly*, it is squeezed as much as possible to force out any scoria. After the whole of the metal is thus formed into balls, the heat of the furnace is still augmented to facilitate the welding. The balls are then lifted out—by means of tongs, if roughing rollers are to be used, or with an iron rod, welded to the ball, if the hammer is to be employed.

The time taken to puddle a charge is from two to two and a half hours. The loss of iron in this process varies considerably, both according to its quality, and also the expertness of the workman. The loss is on an average about ten per cent. During this operation, a considerable quantity of scoria, which sweats out from the metal, is allowed to run off from the hearth, and is removed. The composition of this scoria differs little from that of the refining furnace, except that a quantity of the iron is found in the state of sesquioxide. The following is the analysis of two samples of scoria, the one exposed in a flue of a puddling furnace for some time, and the other, called *tap cinder*, direct from the furnace:—

	Scoria found in flue.		Tap cinder.
Silica,	29·60	....	23·86
Protoxide of iron,	48·43	....	39·83
Sesquioxide of iron,	17·11	....	23·75
Protoxide of manganese,	1·13	....	6·17
Alumina,	1·28	....	·91
Lime,	0·47	....	·28
Magnesia,	·35	....	·24
Phosphoric acid,	1·34	....	6·42
Sulphide of iron,	1·61	....	·62
	101·32		180·02

These results show the impurities to be of the same kind as those of the scoria given out at the refining or running-out furnace.

The following are analyses of refined or malleable iron of different qualities, and from various localities, exhibiting the extent of the effects produced by refining, when compared with the composition of crude iron:—

	Iron.	Carbon.	Sulphur.	Phosphorus.	Silica.	Arsenic.	Copper.	Manganese.
Swedish from Danemora,	98·78	0·84	—	—	0·12	0·02	0·07	0·05
Swedish common bar,	99·73	0·24	—	trace.	0·03	—	—	trace
German very strong rod,	99·13	0·66	—	—	trace.	—	0·05	0·29
German strong, Hartz Mountains,	98·88	0·40	trace.	—	0·01	—	0·32	0·30
German weak, fibrous,	99·87	0·09	trace.	—	0·03	—	—	—
Welsh puddled iron,	98·90	0·41	—	0·40	0·08	—	—	0·04

In comparing these analyses with the qualities, it is difficult to say wherein lies the difference. That termed weak is the purest, and the strong Swedish iron appears the most impure.

CALVERT and JOHNSTON have recently carried out a series of researches, instituted for the purpose of ascertaining the progressive chemical changes effected in the operation of puddling.

The material operated upon was good cold-blast Staffordshire iron, No. 3, rather grey. The puddling was conducted in the usual manner; and at intervals portions of the iron were taken out from the mass, and subsequently analysed so as to ascertain the nature of the changes produced at the different stages of the operation.

The following table gives the quantity of the several portions, so far as regards the per centage amounts of carbon and silicium, which embrace what are considered the principal changes in this process:—

Pig-iron used.	Time.	Carbon.	Silicium
Iron as put in,	12 o'clock.	2·275	2·720
Sample 1	12·10	2·726	·915
" 2	1·0	2·905	·197
" 3	1·5	2·414	·194
" 4	1·20	2·305	·182
" 5	1·35	1·647	·183
" 6	1.40	1·206	·163
" 7	1·45	0·963	·163
" 8	1·50	0·772	·168
Puddled bar,		0·296	·120
Wire bar,		0·111	·088

These interesting results show the value of such investigations; and it is to be hoped that similar experiments will be repeated again and again under various circumstances, and with a view to all the impurities. One thing worthy of notice is the fact, that, after the furnace operations are complete, the hammering and rolling seem to eliminate a great quantity both of the carbon and silicium. The carbon in the wire-iron is only one-seventh of that in the iron at the end of the puddling operations, and the silicium is reduced nearly one-half.

With regard to the sulphur and phosphorus in the iron before and after the puddling, the final results only are given, namely:—

	Pig-iron.	Puddled bars.	Wire-iron.
Carbon,	2·275	0·296	0·111
Silicium,	2·720	0·120	0·088
Phosphorus,	0·645	0·134	0·117
Sulphur,	0·301	0·139	0·094

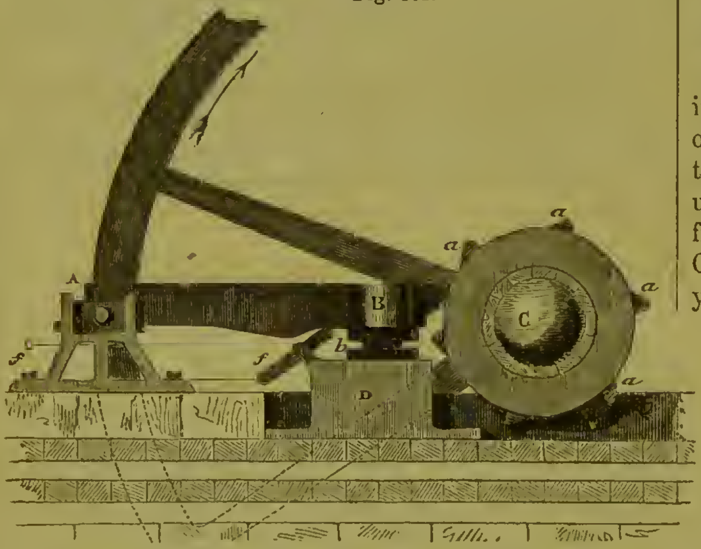
The following composition of the slag produced in these operations confirms the preceding results:—

Silica,	16·53
Protoxide of iron,	66·23
Sulphide of iron,	6·80
Phosphoric acid,	3·80
Protoxide of manganese,	4·90
Alumina,	1·04
Lime,	0·70
	100·00

Hammering, Squeezing, and Rolling.—The process of refining and toughening the iron after passing through the puddling furnaces, is completed by mechanical means; either by subjecting it to the action of large hammers, or by pressing and drawing it between rollers, during which operations a great quantity of scoriaceous matter is squeezed out, and the iron assumes a fibrous structure, possessing the malleable and ductile qualities of wrought-iron. In the first place, the puddled balls are *shingled* or fashioned into oblong slabs or *blooms* by the blows of a heavy forge hammer, termed the *helve*. The blooms are then passed through a series of grooved iron rollers, which reduce them to the form of long bars. These are cut up into short pieces, several of which are *fagoted* together and brought to a welding heat in the *balling* furnace, after which they are again passed several times between grooved rollers, and by this latter process are made into bars or plates, ready for the shears.

The helve or shingling hammer is a ponderous beam of cast-iron, A B—Fig. 302—about ten feet long, and weighing from three to four tons. At one extremity, A, it turns on an axis, which rests on heavy plummer blocks, and to the other is secured the *head*, B, which is of wrought-iron, faced with steel, and weighs from seven to eight hundredweight. The anvil, *b*, is supported on a massive block of iron, D. The head is raised by a number of cams, *a a*, fixed to a powerful shaft, C, which is turned by steam or water-power, assisted and regulated by a heavy fly-wheel. The ball or bloom is placed upon the anvil, and the head, being lifted from eighteen to twenty-four inches by each cam as it revolves, makes from seventy-five to one hundred blows per minute, by which the scoriæ and other impurities are separated.

Fig. 302.



Another instrument used for preparing the blooms to pass through the rollers, acts by compression like a pair of pliers, and is termed the *squeezer* or *alligator*. This machine is represented in Fig. 303. It acts by means of two powerful jaws, A B, united at C like a pair of shears, and having their faces grooved in order to hold fast the bloom, which is introduced between them. A current of water flows through a cavity in the lower jaw to keep it cool. The upper jaw alone moves, and is worked by a cam on the axis, E, of the fly-wheel, operating on the crank, D. This machine requires an attendant to keep the bloom rolling about between the jaws, A B.

The alligator is said to squeeze out the slag more thoroughly and expeditiously than the helve does; but both are now being rapidly superseded by steam-hammers, one of the most celebrated of which is that of NASMYTH, patented in 1833. The hammering weight in this machine is attached directly to the lower end of the steam piston-rod, and the percussive action of the blows is found to be objectionable in its effect upon the piston and rod, causing wear and serio fractures. To obviate this practical defect, Mr. JOHN CONDIE, of the Govan Iron-works, Glasgow, about the year 1846, gave the subject much consideration, and the result of his deliberations was the hammer delineated in Fig. 304. The great difference between CONDIE's hammer and all earlier contrivances, consists in the fact that the steam cylinder is movable, and itself gives the blow, whilst the piston and its rod are fixed to the framing. The cylinder is, therefore, constructed of great strength, particularly at the lower end, which is formed with a dovetail socket, to receive the acting hammer face. This arrangement permits of the replacement of the striking portion when worn.

Fig. 303.

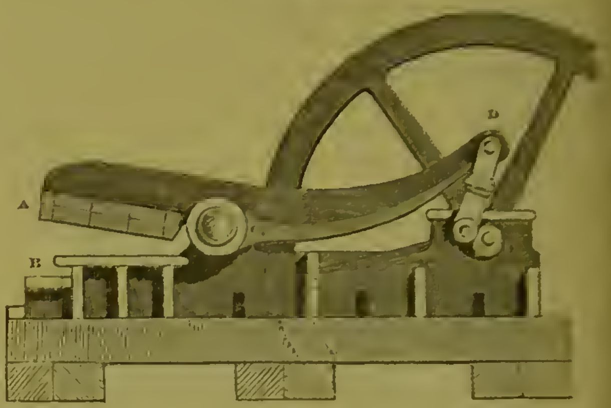
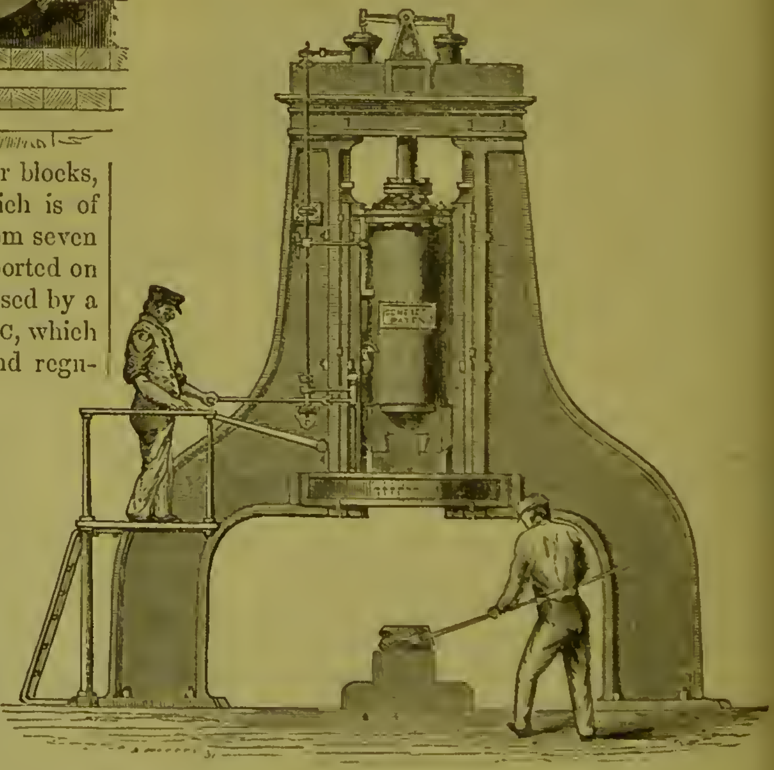


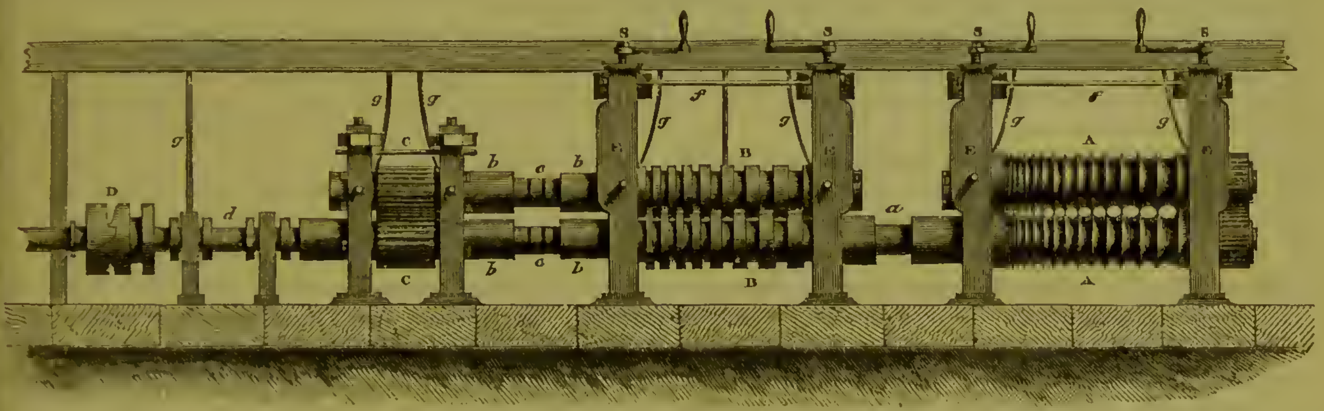
Fig. 304.



The first experimental Condie hammer was erected at the Govan Iron-works in 1848, and it has worked day and night since that time, doing all sorts of puddling and forging work in a most successful manner. The size of the instrument has gone on increasing in quick gradations until the climax of a six and a half tons dead hammering weight, with a fall of seven feet six inches, has been reached. All the unprecedentedly heavy shafts in the great steamer, the *Leviathan*, were forged under Mr. Condie's hammers at a time and under circumstances when such heavy masses could not have been shaped elsewhere. For puddling forges, hammers of forty and fifty hundredweight are now generally superseding the old-fashioned helves and squeezers.

Among the latter class of machines, however, Brown's patent squeezer is acknowledged to be very effective. It consists of a series of massive rollers, so arranged that the heated bloom of puddled iron, being placed on the top of the machine, is taken in between the two upper rollers, and is gradually compressed between these and others as it descends. At the bottom, it falls upon an endless revolving chain ladder, by which it is elevated and thrown on to a platform in front of the rolls for drawing it out into bars.

Fig. 305.

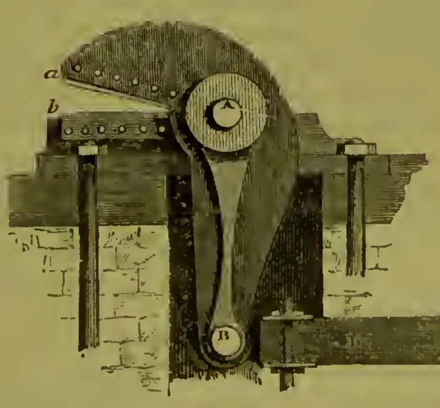


The drawing rolls are represented in Fig. 305, and consist of two sets, A A and B B. The former are called the *roughing* rolls, and serve to conclude the refining process by expressing the last portions of slag; the latter are termed the *finishing* rolls, and are differently grooved, according to the section intended to be given to the bar. They are mounted in pairs, one above the other, on massive iron bearers, E E; the lower rolls are driven direct by a shaft, *d*, from the fly-wheel of the engine, and motion is communicated to the upper rolls by strong toothed wheels, C C; the distance between them is regulated by screws, S S, which work through the tops of the bearers. These are connected at the upper part by stout iron bars, *f f*, which serve to support the heavy tongs employed in lifting the blooms. Through the small pipes, *g g*, a stream of water is made to play upon each pair of rolls, to keep them cool, descending into a channel beneath the frame, in which the scale that falls from the surface of the heated iron, as it passes between the rolls, is carried away by the water. The roughing rolls vary from four to five feet long, and are about eighteen inches in diameter.

The bloom on arriving at the platform in front of the roughing rolls, is still at a bright heat, and is now of an oblong form. The workman immediately seizes it with a pair of tongs, and forces it into the largest groove in the rolls, the first three or four grooves being roughened with teeth, by which it is caught, and carried through without slipping. It is then passed in succession through the other grooves of the same series, until it attains the required form for railway bars or other purposes to which it is intended to be applied.

For good bar-iron, however, an additional process is required. When the blooms have been reduced by the roughing rollers to the form of long bars, they are cut into short lengths, which are welded together in piles, and again drawn out into bars in the rolling mill. A great variety of shears is used for cutting iron, some driven by cams or eccentrics, and some by connecting rods and a crank on the revolving shaft. In large iron-works it is necessary to have two or three kinds, some for cutting up scrap iron and bars for piling, and others for boiler-plates. The shears employed in cutting the bars for piling consist of two jaws, Fig. 306, to which are firmly bolted cutting edges, *a b*, of hardened steel. The lower blade, as in the squeezer, is fixed, but the upper one moves on the pin, A, by the action of the bar, D, on the lever, B A. Bars of considerable thickness are easily divided by the jaws, and a number of the short lengths thus produced are placed together in *piles* or fagots, which are raised to a welding heat in a reverberatory furnace, taking care not to expose them to the oxidising influence of the air. The experience of the workman enables him to judge, from the appearance of the furnace, when the piles are at a welding heat, so that, when afterwards compressed in the rolls, the particles will unite. When he ascertains that this point has been attained, the piles are taken

Fig. 306.



out, one at a time, and thrown to the workmen at the finishing rolls, who pass them through the grooves as rapidly as possible, so as to elongate each pile into a bar of the required size, before the iron has cooled down below the proper temperature for drawing. The short lengths which compose the pile or fagot tend to produce a fibre in the bar, which in good iron is always perceptible, however perfect the weld, and seems to be necessary to give it strength and toughness.

Sheet-iron is made by passing the metal between smooth rollers, without grooves, the rollers being gradually screwed nearer together as the desired thickness is being approached.

The speed of the different kinds of rolling mills varies according to the work they have to perform. Those for merchant-bars make from sixty to seventy revolutions a minute, whilst those of large size for boiler-plates are reduced to twenty-eight or thirty. Others, such as the finishing and guide rollers, run at from one hundred and twenty to four hundred revolutions a minute.

Bessemer's Process.—The nature of the changes taking place in the iron during the preceding refining operations is obvious, the whole being simply a process of oxidation of the impurities, which are subsequently squeezed out by the pressing and rolling. Since the invention of puddling by Mr. Cort, many improvements or alterations, both of a chemical and mechanical nature, have been introduced, some of which have done much to facilitate the operations; but all have been merely modifications of the same principle: the process was still essentially Cort's. But during the year 1856, a method was patented which sets all previous plans and modifications aside, and, as with the wand of the magician, effects the refining of the iron from the crude pig to malleable bar without either fuel or hammer. Unfortunately, from various experiments tried, the practical utility of this beautiful process is still doubtful. Mr. Bessemer, the inventor, describes it in nearly the following terms, in a paper which was read before the British Association in the year above-mentioned:—

The assumptions with which he set out were, that crude iron contains about five per cent. of carbon; that carbon cannot exist at a white heat in the presence of oxygen, without uniting therewith, and producing combustion; that such combustion would proceed with a rapidity dependent on the amount of surface of carbon exposed; and, lastly, that the temperature which the metal would acquire would be also dependent on the rapidity with which the oxygen and carbon were made to combine, and consequently that it was only necessary to bring the oxygen and carbon together in such a manner that a vast surface should be exposed to their mutual action, in order to produce a temperature hitherto unattainable in our largest furnaces. With a view of testing practically this theory, he constructed a cylindrical vessel of three feet in diameter, and five feet in height, somewhat like an ordinary cupola furnace, the interior of which was lined with fire-bricks; and at about two inches from the bottom of it, he inserted five tuyere pipes, the nozzles of which were formed of well-burnt fire-clay, the orifice of each tuyere being about three-eighths of an inch in diameter. At one side of the vessel, about half-way up from the bottom, there was a hole made for running in the crude metal, and in the opposite side there was a tap-hole stopped with loam, by means of which the iron could be run out at the end of the process. In practice this converting vessel might be made of any convenient size, but he preferred that it should not hold less than one, or more than five tons of fluid iron at each charge. The vessel was placed so near to the discharge-hole of the blast-furnace as to allow the metal to flow along a gutter into it; a small blast-cylinder was employed, capable of compressing air to about eight or ten pounds to the square inch. A communication having been made between it and the tuyeres before named, the converting vessel was in a condition to commence work.

It has been stated that the tuyeres were situated nearly close to the bottom of the vessel; the molten mass would, therefore, rise some eighteen inches or two feet above them. It was, consequently, necessary, in order to prevent the metal from entering the tuyere holes, to turn on the blast before allowing the fluid crude iron to run into the vessel from the blast-furnace. This having been done, and the liquid run in, a rapid boiling up of the metal was heard going on within the vessel: the metal being tossed violently about and dashed from side to side, shaking the vessel by the force with which it moved. Flame then issued from the throat of the converting vessel, accompanied by a few bright sparks. This state of things continued for about fifteen or twenty minutes, during which time the oxygen in the atmospheric air combined with the carbon contained in the iron, producing carbonic acid gas, and at the same time evolving a powerful heat. Now, as this heat was generated in the interior of, and was diffused in innumerable fiery bubbles through, the whole fluid mass, the vessel absorbed the greater part of it; its temperature became immensely increased; and by the expiry of the fifteen or twenty minutes before named, that part of the carbon which appeared mechanically mixed and diffused through the crude iron was entirely consumed. The temperature, however, was so high, that the chemically-combined carbon now began to separate from the metal, as was at once indicated by an immense increase in the volume of flame rushing out of the throat of the vessel. The metal in the vessel now rose several inches above its natural level, and a light frothy slag made its appearance, and was thrown out in large foam-like masses. This violent eruption of cinder was generally found to last about five or six minutes, when all further appearance of it ceased, a steady and powerful flame replacing the shower of sparks and cinders which always accompanied the boil. The rapid union of carbon and oxygen which thus took place, added still further to the temperature of the metal, while the diminished quantity of carbon present allowed a part of the oxygen to combine with the iron, which underwent a combustion and was converted into an oxide. At the excessive heat which the metal had now acquired, the oxide as soon as formed underwent fusion, and formed a powerful solvent of those earthy bases which were associated with the iron. The violent ebullition which was going on mixed most intimately the scoria and metal, every part of which was thus brought in contact with the fluid oxide, which thus washed and cleansed the metal most thoroughly from the silica and other earthy bases combined with the crude iron; while the sulphur and other volatile matters which cling so tenaciously to iron at ordinary temperatures were driven off, the sulphur combining with the oxygen and forming sulphurous acid. The loss in weight of crude iron during its conversion into an ingot of malleable iron, was found on a mean of four experiments to be twelve and a half per cent., to which would have to be added the loss of metal in the finishing rolls. This would make the entire deficiency probably not less than eighteen per cent., instead of about twenty-eight per cent., which is the loss on the present system. A large portion of this metal was, however, recoverable, by treating with carbonaceous gases the rich oxides thrown out of the furnace during the boil. These slags were found to contain innumerable small grains of metallic iron, which were mechanically held in suspension in the slags, and might be easily recovered.

It has been stated, that after the boil had taken place, a steady and powerful flame succeeded, which continued without any change for about ten minutes, when it rapidly fell off. As soon as this diminution of flame is apparent, the workman will know that the process is completed, and that the crude iron has been converted into pure malleable iron, which he will form into ingots of any suitable size and shape by simply opening the tap-hole of the converting vessel and allowing the fluid malleable iron to flow into the iron ingot moulds placed there to receive it. The masses of iron thus formed, are found to be perfectly free from any admixture of cinder, oxide, or other extraneous matters, and are far more pure, and in a forwarder state of manufacture, than a pile formed of ordinary puddle bars. And thus it will be seen, says Mr. Bessemer, that by a single process, requiring no manipulation or particular skill, and with only one workman, from three to five tons of crude iron pass into the condition of several piles of malleable iron in from thirty to thirty-five minutes, with the expenditure of about one-third part the blast now used in a finery furnace with an equal charge of iron, and with the consumption of no other fuel than is contained in the crude iron.

To those who are best acquainted with the nature of fluid iron, it may be a matter of surprise that a blast of cold air forced into melted crude iron is capable of raising its temperature to such a degree as to retain it in a perfect state of fluidity after it has lost all its carbon, and is in the condition of malleable iron, which, in the highest heat of our forges, only becomes a pasty mass. But such was the excessive temperature which Mr. Bessemer was enabled to arrive at with a properly-shaped converting vessel and a judicious distribution of the blast, that the fluidity of the metal was not only retained, but so much surplus heat created, as to re-melt the crop ends, ingot runners, and other scrap that was made throughout the process, and thus to bring them without labor or fuel into ingots of a quality equal to the rest of the charge of new metal.

The ingots of malleable metal so formed, were found to have no hard or steely parts, such as exist in puddling iron, requiring a great amount of rolling to blend them with the general mass; nor do such ingots require an excess of rolling to expel cinder from the interior of the mass, since none can exist in the ingot, which is pure and perfectly homogeneous throughout, and hence requires only as much rolling as is necessary for the development of fibre.

One of the most important facts connected with Mr. Bessemer's system was stated to be, that all the iron so produced was of that quality known as charcoal iron: not that any charcoal is used in its manufacture, but because the whole of the processes following the smelting of it are conducted entirely without contact with or the use of any mineral fuel; the iron resulting therefrom being, in consequence, perfectly free from those injurious properties which that description of fuel never fails to impart to iron that is brought under its influence. At the same time, this system of manufacturing malleable iron was considered as offering extraordinary facility for making large shafts, cranks, and other heavy masses; since any weight of metal that can be founded in ordinary cast-iron by the means at present in common use, could thus be founded in molten malleable iron, and be wrought into the forms and shapes required, by simply increasing the size and power of the machinery to the extent necessary to deal with such large masses of metal.

So far as the principle of Mr. Bessemer's process is concerned, it is certainly a beautiful application of chemical knowledge to practical purposes; but in its present probationary state it would be premature to venture more than a congratulation to the inventor upon the correctness of his inductions, although many of the most ingenious theories have been found inapplicable, from some cause involved in the very nature of the operation. What could have been more beautiful than Davy's application of zinc protectors to the copper sheathing of ships, or what more completely successful in accomplishing the object intended; and yet its perfect success was the cause of its being unsuitable. One evident defect in the practical result of the process, is its failure to free the iron from phosphorus and sulphur, which is certainly a serious drawback, as shown by the following analysis of iron refined by this method:—

Iron,..................................	98·90
Carbon,..................................	0·05
Sulphur,..................................	0·16
Phosphorus,..................................	1·08
	100·19

From the analyses of wrought-iron which have been given, it will be seen that its comparative weakness or strength has no apparent relation to its chemical purity; a circumstance suggesting the probability that there may also be mechanical requirements in preparing malleable iron, which the puddling process supplies. Mostly all metals, when melted and left to solidify undisturbed, do so in a crystalline form. The stirring and working in the puddling operations may prevent this crystallization in the metal, and hence the tenacious and fibrous character of wrought-iron. Time and experience are required to prove the practicability of the best inventions, and these often enable the experimenter to modify the processes, so as to overcome the collateral difficulties that arise in the first applications. Should such difficulties exist in the present case, Mr. Bessemer will have the sympathy of all men of science, and their best wishes for the success of a process at once beautiful, ingenious, and simple. It may be remarked here that perfectly pure iron seems not to be desirable; it is very malleable and ductile, and might do for wire, but its softness would be a considerable objection for many requirements. The iron wanted must be hard as well as tough, and this is the object to be aimed at.

Loss in Refining.—On looking back upon the refining operation, the quality of the crude iron from the blast furnace, and the state of the malleable iron produced, there is one circumstance which must strike every reader with surprise; namely, the great loss of metal which takes place in the refining. Something is evidently wanting in the process to reduce this deficiency Mr. Bessemer gives the loss in the common process at twenty-eight per cent.; of course this will vary according to the quality of the cast-iron used, but in many localities the loss has been found to average nearer thirty-three than twenty-eight per cent. The proportion of loss will be more apparent when stated thus:—If pig-iron having six per cent. of silica be refined with coke containing three or four per cent. of the same substance, and if, as shown by the analysis of the cinder, every part of silica represents three of protoxide of iron, consequently the gross loss cannot be much less than one-third of the pig-iron, especially when one takes into consideration the other sources of silica with which the iron may be brought into contact in the process of refining both in the running-out and puddling furnaces. Even in the mere operation of remelting to produce cast-iron articles for machinery, the loss from the formation of cinder is very considerable.

The cinder, however, although lost to the manufacturer of malleable iron, is not entirely thrown away; in many places it is collected and re-smelted with lime flux, by which an inferior iron is obtained. It is also often mixed in small quantities with the ordinary ores in the blast furnace; but their presence generally affects the quality of the iron produced. A patent was recently taken by Mr. Calvert to recover the iron from rich cinders; but no good and effective method has yet been applied.

Swedish Iron.—Notwithstanding the facilities enjoyed in this country, and the great improvements in the manufacture of iron, still the qualities produced on different parts of the Continent are preferred—particularly those of Sweden, Norway, and Russia—and command a higher price in the English market than the British best iron; but the ores from which the iron of these countries is made are much richer, the quantity of iron produced is less, and the fuel is of a superior kind, namely, charcoal.

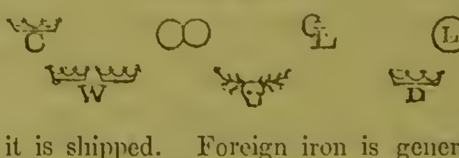
At the smelting works of Sweden and Norway, the principal ores from which the iron is manufactured are the magnetic oxide, the composition of which has been already given. According to M. Jars, the smelting furnaces of Sweden and Norway are about thirty feet high from the tuyere-hole to the base of the chimney. The time required by the ore to descend from the top of the furnace to the tuyere is very considerable, during which time it is mixed up with charcoal under the effects of a constant and regularly increasing heat; and the ore, having little or no earthy matters in it, the iron is gradually reduced to the metallic state by loss of its oxygen, and then by an increased heat it combines with from three to six per cent. of carbon, in which state it is more easily kept in a fused condition. This fused metal runs down into the hearth, and is from time to time let out, as in the process of smelting in this country. It is then introduced into a refining furnace, which consists of a low quadrangular stack of masonry, with a sloping ledge inside, just opposite the tuyere-hole, and on this the crude-iron is placed and covered with charcoal, to prevent the iron from burning away by the action of the blast, which is directed so as to strike upon the under surface of the pig, and the latter is pushed forward from time to time in proportion as the lower part is melted away by the blast. When all is fused, a man with an iron bar keeps stirring and intermixing, while the blast is continued. In a short time jets of flame arise from the surface of the metal, and soon after it becomes of a thicker consistence; it is then gradually solidified, and is removed from the furnace to the hammer. How close is this in principle to Bessemer's new process?

The scoriæ stirred into the melted metal, says Berzelius, consist of oxide of iron vitrified with silica and other earthy substances, all of which contain oxygen, and this, reacting on the carbon of the cast-iron, separates it in the state of inflammable gas—carbonic oxide. The best quality of Swedish bar-iron was found by the above-mentioned illustrious chemist to contain half a per cent. of carbon and one-tenth of a per cent. of silicium.

As already stated, much of the superior quality of the iron produced in these countries depends more upon the purity of the ore and the fuel, than on any difference in the mode of manufacture. When coke or mineral coal is used by the same method, and for the same ores, the iron produced is very inferior; and when the ordinary ore of this country is treated by the same process, even with charcoal, the iron produced is not equal to that made from the best ore and charcoal, showing how much depends upon the character and quality of the fuel.

The most celebrated iron mine of Sweden is that of Dannemora, about thirty miles to the North of Upsala. It is imported into England, chiefly at Hull, and is known as *Oregrund* iron, from the name of the port at which it is shipped. Foreign iron is generally imported in bars, on which certain marks are stamped by the manufacturers. The marks which distinguish the Swedish iron are shown in Fig. 307. The different qualities of the Oregrund are known as the *hoop L*—so called from being marked with the letter L enclosed

Fig. 307.



in a circle or hoop—the *G L*, and the *double bullet.* Inferior Swedish iron is known by the marks *C and crown*, *D and crown*, the *steinbuck*, and the *W and crowns.*

STEEL.—Steel is a compound of iron and carbon, nearly in the proportion of five equivalents of carbon and seventy-three equivalents of iron, giving the formula $Fe_{73}\ C_5$, and is manufactured from the purest malleable or bar iron, such as the charcoal iron of Sweden and Russia. It is generally divided into four qualities—namely, Damascus steel, German steel, blister steel, and cast-steel.

Damascus steel derives its name from the city of Damascus in Asia, which, from the earliest time, has been famed for producing a steel of remarkably superior quality, and eminently fitted for swords or scimitars—hence Damascus *blades* have long been proverbial. The surface of these blades presents a variegated appearance of *watering* in white and black lines. A similar effect has been given to other steel; but the quality of the metal has never been surpassed in this country. It is of the nature of cast-steel, and is a little more highly charged with carbon than European steel, but the characteristic quality of metal is obtained by some peculiar mode of cooling and conducting the operations.

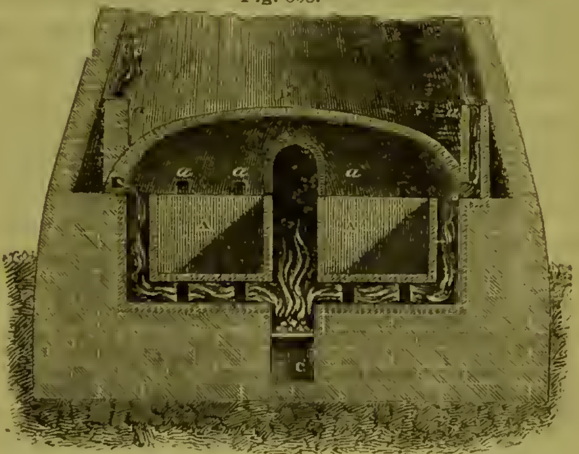
M. BREANT, who devoted much time to the production of this kind of steel, made some excellent blades by mixing one hundred parts of soft iron with two parts of lamp-black, and fusing. This was considered an easy method of making cast-steel without the previous cementation of the iron. A good Damascene steel was also obtained by mixing one hundred parts of the best grey cast-iron with an equal amount of the same iron reduced to filings and oxidised, and then fusing the two together. This gave a metal remarkable for its elasticity. In making this steel, care should be taken to stir the materials during their fusion, before they are allowed to set. The iron filings should be as fully oxidised as possible before being used; for when the carbon is in excess, the steel produced is difficult to forge, except within a very narrow range of heat, and the proper temperature has to be carefully watched.

Indian steel is found very difficult to work in this country, in consequence of our workmen not studying the particular temperature at which alone the steel will forge easily. Experience, says URE, has taught that the orbicular veins which are seen upon the finest Eastern scimitars are the result of the manner of forging them, as well as the method of twisting the Damascus bars. If these be drawn in length, the veins will be longitudinal; if they be spread equal in all directions, the stuff will have a cylindrical aspect; if they be made wavy in the two directions, undulated veins will be produced like those in the Oriental Damascus.

The mode of manufacturing steel in the East, at the present day, is probably the same as was practised in the earliest age in which there is any reference in history to the use of that article. The iron is made from the magnetic oxide by the means which were formerly adopted in the old bloomeries. When about to be converted it is made into small pieces, and packed in crucibles formed of clay. From one to two pounds of iron is put into each crucible with about one-tenth of its weight of chopped wood, and is then covered with clay to exclude the air. When the crucibles and covers are dry and well tempered, about twenty-four of these are built in the form of an arch within a small furnace; the whole are then covered over with charcoal, the mass is ignited, and the fire is kept up by a blast during from two to three hours, when it is allowed to go down, and the crucibles are removed. When cold, they are broken, and the steel is obtained in the form of a cake at the bottom. This product is known as Indian steel, or wootz, and is said to be superior to the best English steel for the purposes of fine cutlery.

BLISTERED STEEL, OR STEEL OF CEMENTATION, is largely manufactured in Great Britain, particularly in Sheffield. The furnace in which the operation is conducted is represented in Fig. 308. C is the grate and hearth; A A are chests or troughs made of the best fire-clay; *a a* are flues leading to the chimney to assist the draught; and at the back is a door by which the men enter for the purpose of filling and emptying the troughs. The whole is built under a large cone or chimney, from forty to fifty feet high, resembling the dome of a glass-house.

Fig. 308.



The troughs are of various dimensions, according to the size of the furnace and the taste of the manufacturer, varying from eight to sixteen feet in length, and from two to three feet in width, and the depth generally corresponding to the width. Small troughs are considered to produce the most uniform quality of steel. They are so set in the furnace, that a space is left under and round the sides, to allow the flame of the fire to play all round them. The troughs are charged by laying first in the bottom a layer of about two inches of fine charcoal-powder, mixed up with one-tenth of ashes and common salt, which is technically called the *cement.* Upon this are placed the bars of iron, separated from each other about half an inch; and upon these is laid, to the thickness of one inch, more of the charcoal-powder, and then another layer of bars; and so on in successive strata, till the trough is filled to within a few inches of the mouth; the remaining space is filled up with old cement-powder, and there is then put upon the whole as a covering a layer of damp sand, or fire tiles.

The furnace is now fired, and heated carefully till the temperature of the trough reaches about 100° Wedgwood, which should take from three to four days. This temperature must be steadily maintained until pieces of the metal, taken out by *proof-holes* at the ends of the troughs, show the process of conversion into steel to be complete, which requires, according to circumstances, from four to eight days. A few of the bars are allowed to project for this purpose. When the furnace is cooled, the troughs are opened and the steel-bars removed; they are found to be covered with blisters, and hence the term *blistered steel.* This steel is irregular in its texture, and has more or less of a crystalline appearance in proportion to the carbon absorbed. It is then subjected to the operation of tilting under powerful hammers, by which it is made more uniform, and fit for any useful process in tool-making. Good blistered steel should be of a greyish color, and possess a bright lustre, and should exhibit a coarse grain of a lamellar structure. That which is of a white color and fine-grained is inferior.

In the process of conversion much depends upon the degree of heat, and the regularity at which the heat is maintained, for producing a good article. No small experience is required for properly conducting these operations; and even with the most careful workmen, the charge occasionally proves bad. When the iron is good, it augments in weight during its conversion into steel; but bad iron increases very little. The best iron for making blistered steel is that from Sweden, although some English charcoal iron has occasionally produced very good steel.

Shear-Steel.—Shear-steel is made from blistered steel; and is so called from the circumstance of the shears used for dressing woollen cloth being made from it, although it forms also the material of many other important manufacturing tools. It is prepared by binding together with a slender steel rod several short lengths of blistered steel, one of which is left longer than the rest, or a pole of iron is used for a handle, as shown in Fig. 309. The fagot is then put into the hearth of the forge, and brought to a welding heat, a little sand being sprinkled over the bars, to produce a skin of scoria or glass over the surface, so as to protect them as much as possible from the air. The fagot, when removed from the furnace, is placed under a forge-hammer, which unites all the fragments, and closes up the internal fissures and cavities that always exist in blistered steel. A solid mass or bar is thus produced, which is again heated, the binding rings are knocked off, and the tilt-hammer, Fig. 310, comes into operation. This machine is similar in principle to the shingling hammer already described; but in shingling, where only a slow motion is required, the hammer is lifted up by means of levers attached to a cam revolving under the nose of the helve, whereas in the tilt-hammer the cogs of a wheel, B, are made to act upon the tail, D, of the helve, pressing it down, and thus causing an elevation of the head of the hammer with a greater rapidity of motion, on account of the comparatively small arc described by the tail. The helve of the tilt-hammer is made of timber secured by wrought-iron rings, and the head, which is also of iron, falls from two to four hundred times per minute upon the mass of steel, *b*, which is placed on the solid anvil, *a*. The workman is seated on a board suspended by iron rods from the ceiling of the mill-house, whereby he is enabled, with a slight motion of his foot, to advance or recede, and holding in his hand the pole, o, Fig. 309, to cause every part of the welded pile to receive the blows of the hammer in quick succession. By this operation, the steel is formed into bars of about an inch and a half broad, and three-eighths of an inch thick; all the seams and fissures of the blistered steel are closed, and it is now capable of being forged with the hammer into shears, edge-tools, and cutting instruments, or drawn out by rollers according to the use for which the metal is to be applied.

Fig. 309.

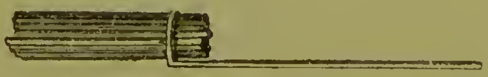
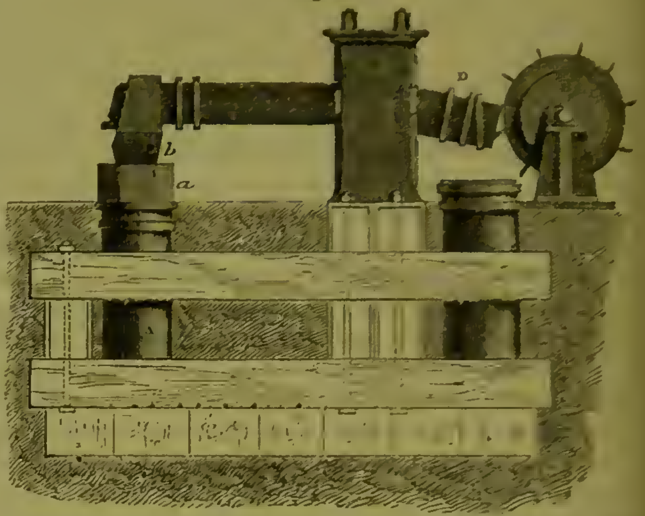


Fig. 310.



During these operations, even when great care is taken, the steel loses a portion of its carbon; and much attention is required to prevent its being reconverted into common iron. Shear-steel is more compact, malleable, and ductile than blistered steel, and much more easily wrought into shape.

Cast-Steel is much harder, and much less malleable and ductile than shear or blistered steel, but may be wrought at a certain temperature; and, consequently, great care is required to notice the particular degree of heat required for the working of it. It is made by taking the most highly carbonised blistered steel, breaking it into convenient pieces, packing them into a crucible along with a little slag or broken glass to protect from oxidation, and fusing in a wind furnace. The crucibles for this purpose are made of very refractory clay, mixed with a small quantity of coke dust, and kneaded with the naked feet during five or six hours. This is put into a cylindrical mould of cast-iron, *a*, Fig. 311, which is open at both ends, and is inserted into a sole, *b*, also of cast-iron. In the centre of the sole, corresponding with the axis of the cylinder, is a hole to receive the supporting-rod of the inner mould, *c*, which consists of a block of hard wood. Through the centre of this block passes a strong iron axis, the upper part of which is rounded into a knob, *d*. The surface of *c*, and the inner surface of *a*, having been smeared with oil, a quantity of clay is put into *a*, and the block, *c*, is then forced down by blows of a hammer, until the lower end of the axis, *d*, enters the hole in the sole, *b*. The black portion around *c*, shows a section of the crucible thus formed. To disengage it from the mould, the interior block or core is pulled out by means of the handle, *d*, and the hole made in the bottom of the clay by the lower end of the axis is filled up. The mould, *a*, is then separated from the sole, *b*, and the disc of wood which is seen on the tip of the iron rod, *t*, Fig. 312, is placed for a support under the exposed bottom of the crucible, to which it exactly fits. The exterior mould is then allowed to descend slowly, by which means the clay pot is left upon the top of the block of wood, as shown in the same figure. It is finished by hand, the top being pressed slightly inwards, and made to assume the form represented in Fig. 313. The crucibles are about two feet in height, and weigh about twenty-five pounds. They are placed in short cylinders of clay, *e*, and the covers are thick discs, *f*, of the same material, slightly raised in the centre. Each crucible is removed as soon as it is finished into a heated vault, where it gradually becomes dry, and some hours before being used the crucibles are brought to a red heat, for the purpose of annealing them.

Fig. 311.

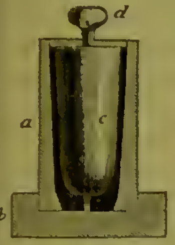
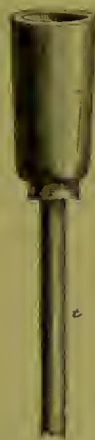


Fig. 312.



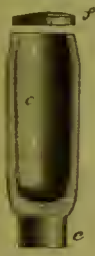


Fig. 313.

The furnace employed for melting the steel is simply a square prismatic cavity, of about fourteen inches on each side, and a depth of two feet. Iron bars are placed to support the fire. In most establishments several of these furnaces are so arranged along the walls, that the mouth is but a little above the floor of the foundry, for the convenience of the men lifting out and putting in the crucibles. The furnaces are also all connected to a chimney, so as to have a strong draught, and obtain a high temperature. The crucible, with its charge of steel, is inserted into the cavity or fireplace, then packed all round and over with coke, and a cover put on the mouth; and in a short time a powerful heat is raised, by which the steel, in the course of from three to four hours, is melted. The crucible is then removed from the fire, the cover taken off, and the steel poured into cast-iron moulds.

Cast-steel is much used for cutting and other edge-tools, being very hard. If a piece of polished iron be placed in the mould when the steel is cast, the iron and steel adhere, and may be rolled together. By this means many edge-tools are made, such as plane-irons, in which the part forming the edge alone is steel; so that not only a much cheaper article is produced, but one having the toughness of ordinary iron, while the cutting part has the hardness of the steel.

Another method of making steel, is by the conversion of cast-iron into what is termed *natural steel*. Much of this quality is prepared in Germany, where the best cast-iron is produced. As the presence of silica and earths in steel is very hurtful, it will be evident that only the purest cast-iron can be employed. The best for this purpose is that made from spathose iron ores, containing a small portion of manganese. The iron to be converted is cast into plates; a charcoal fire is kindled in a hearth, similar to that used for the refining of iron, and the iron plates are melted before the blast; to the fused mass is added a quantity of iron scale and rich scoria, which are considered to assist in the oxidising of the carbon in the iron.

The workman carefully watches the progress of the operation. After a small portion of the iron is melted, it is allowed to stand until, by the oxidising of its carbon, it becomes solidified into a pasty consistence; a little more cast-iron is melted into this, which renders the mass again fluid; after a time, the whole assumes once more its former state, and this operation is repeated, and continues until from three hundred to four hundred pounds of metal are added; care being taken to allow the melting iron to drop into the hearth in the centre of the charge, by which the mass acquires the appearance of a series of rings, the centre portion being fluid, and the rings becoming more and more pasty or spongy towards the circumference. After the scoria is let off, the whole mass of iron is removed from the hearth and cut into pieces in lines radiating from the centre to the circumference; these pieces are drawn into bars, but from the nature of the whole operation, different qualities of steel will exist in the same bar. To remedy this defect, the bars are made red-hot, and plunged into cold water, after which the refiner raises each bar by one end, and brings it down with a slight force upon an anvil placed upon the floor, by which means the most brittle parts of the steel break off, and are collected; after which the remaining portion of the bar is again brought down with a much harder stroke, which detaches other portions of the bar, and thus the different qualities are separated.

The parts broken off are examined, and, according to certain appearances of the fracture, are subjected to other manipulations, to give them density, which is done by welding together pieces of different qualities; the mass is afterwards tested in the same way by the refiner first heating it and plunging it into cold water, and then proceeding as before, repeating these operations till a perfect uniformity is obtained. The whole process must be watched carefully, as the metal gradually loses carbon, and would soon be reduced to common iron; to prevent this, the metal is covered during heating with a mixture of clay and oxide of iron, which forms a slag on its surface protecting it from the blast. These operations produce steel of very excellent quality, but it is at a considerable cost, both of time and material.

In those countries where German steel is made, a remarkable article is manufactured which deserves notice; it is harder than the best steel, and so brittle that it cannot bear any bending when cold. This article is cast-iron. It is derived from the remelted steel-metal. From two hundred to two hundred and fifty pounds of this metal are melted down in the bottom of the forge hearth; a small portion of it is let off; it should be tapped as low at the bottom as possible. This mass, which flows like cast-iron or cast-steel, is broken into small pieces, and pounded into a flat piece of wrought-iron, which has a brim drawn up around it. This piece serves as a crucible. It is covered with loam, and exposed to a heat which will melt the cast-iron, and unite it firmly with the wrought-iron. The former then forms a thin coating of steel over the one side of the iron, of immense hardness. This does not become soft even though a long time is consumed in tempering it. Wrought-iron plates furnished with such a coating of steel, are used as draw-plates for wire. The holes for the wire are punched when it is warm, for, when cold, its hardness is so extreme that no drill-bit can make any impression on it.—*Overman.*

New Processes for Making Steel.—As may be supposed, a manufacture of such importance as steel could not fail to be the subject of many experimental trials and improvements, both in the processes of cementation and casting; and several patents have been taken out for new processes and modifications of the old. Some of these have been successful, and are included in the operations already described; while others have not been sufficiently economical or advantageous to warrant a change from existing plans. A curious and interesting process, considered in its chemical reactions, was suggested several years ago by Mr. MACINTOSH. His apparatus consisted of a furnace constructed in the form of a double cylinder, one surrounding the other, and containing the fire between them; the iron bars, to be converted into steel, were suspended in the internal cylinder; and, when they were at a red heat, there was passed through the interior cylinder a current of common coal-gas which the iron decomposed, combining with the carbon and becoming steel.

So great is the affinity between iron and carbon at a high heat, that at first sight the chemist is surprised to find the process not much more perfect than it really is; for experience teaches that there are many defects in the present modes of manufacture, from causes that have not yet been fully investigated, but which produce great irregularities in the quality and economy of the article. It may be that this same strong affinity between the constituents of steel, and the consequent ease with which the carbon will combine with the iron in different proportions, so as to produce different qualities of compound, may be the origin of the evils felt; and that to produce good steel the carbon and iron must be combined in a certain proportion. To take cast-iron having five per cent. of carbon in it, and at great expense and labor convert this, first into malleable iron by taking away the carbon, and then into steel by giving it back the carbon with equal labor and cost, seems a circuitous operation. If the difference between cast-iron and steel merely consist in the circumstance that the former contains more carbon than the latter, it would appear more consistent to deprive the cast-iron of just so much carbon as would leave exactly the required proportion for making steel. Hence some such process as BESSEMER'S would seem the true course.

Upon this principle is based a patent of F. UCHATINS, the specification of which sets forth the object of the invention to be, to reduce the cost of manufacturing cast steel by economizing the labor of the process. To this end, the inventor takes pig-iron of the purest quality, and melts it in a suitable furnace, and while in a molten state he runs the metal into cold water, and thereby reduces it into granulated iron. It is now in a suitable condition to undergo the process which will convert it into cast-steel. This mode is founded on the well-known fact, that cast-iron enwrapped or surrounded by any oxygenized materials, and subjected to a cementing heat for a given time, will yield up a portion of its carbon, which will combine with the oxygen driven off from the surrounding materials, and form carbonic oxide or carbonic acid gas. If this process is interrupted before completion, a partially decarbonized iron will result, the surface of which will have been converted into a pure iron, while the interior parts remain unchanged; or, in other words, the progress of the decarbonizing action will depend on the amount of metallic surface brought into contact with the oxygen-yielding material with which the iron is surrounded. In order, therefore, to expedite this operation, the pig-iron is reduced, as before mentioned, to a granulated state; and further to economize fuel and labor, the heat required for effecting the decarbonization of the iron is employed to reduce the metal, when sufficiently decarbonized, to a molten state; and thus by one and the same heating it is converted into cast-steel, which only needs to be forged to prepare it for the market. The granulated iron is mixed with about twenty per cent. of roasted pulverized sparry iron ore and four per cent. of fire-clay, and then placed in fire-clay crucibles, and subjected to heat in a cast-steel blast-furnace of an ordinary construction. By thus subjecting the granules of iron in presence of the sparry iron ore to a melting heat, the enwrapping oxides will first effect a partial decarbonization of the granulated iron, which decarbonization will be limited in amount according to the size of the granules operated upon; and by reason of the continued application of heat, the iron will melt and separate, with the assistance of the melting residues of sparry iron ore, from the impurities with which it was mixed, and also bring down with it a portion of the iron contained in the sparry iron ore, thereby increasing the yield of cast-steel by about six per cent.

The quality of the steel is capable of being by this process considerably modified. Thus the finer the pig-iron is granulated, the softer will be the steel made therefrom. The softer sorts of welding cast-steel may be obtained by an addition of good wrought-iron in small pieces, and the harder qualities by adding charcoal in various proportions to the before-mentioned mixture.

CASE-HARDENING.—Thin films of steel are formed upon the surface of iron articles, such as keys, gun-locks, tools, *et cetera*, by a process technically termed case-hardening. The article to be case-hardened is finished, or nearly so, in iron, and then heated to a bright red. When in this state, it is sprinkled or rubbed over with powdered yellow prussiate of potassa—ferrocyanide of potassium. The salt is decomposed by the heat and iron, and the surface combines with the carbon of the salt, forming steel; or the operation may be performed by making a strong solution of ferrocyanide of potassium in water, then adding clay to make a thin paste. The iron article to be hardened is coated over with this paste, and dried slowly at a fire; it is then submitted to a white heat, and afterwards plunged into water when the heat has become reduced to a visible red.

Tempering.—One characteristic quality of steel is its being susceptible of having its hardness much increased by heating it strongly, and plunging it while hot into cold water. Different qualities of steel are affected in different degrees by this process of *tempering*. To know the degree of heat which is best fitted for any particular quality of steel, requires much experience. The practical test is to draw a bar into a tapered point, such as a chisel, and temper it; the thin tapered part will be variously affected in the process by the different rates of heat and cooling; by breaking off pieces from the point inwards the character of the grain will show the difference of temperature which has been applied; the finest and closest grain being considered the best. Such steel, then, is tempered with due relation to the test heat. The degree of hardness depends, in a great measure, upon the heat of the steel, and the coldness of the medium in which it is cooled. To give different effects different mediums are used, such as saline solutions instead of water. Mercury and oil are also employed. By this tempering process, steel may be made of any degree of hardness. The common method is to heat the steel and harden it in water, and then to anneal it, by reheating to a particular temperature, such, for instance, as that at which tallow or oil will burn when put on it; or the steel, being ground and polished, is then reheated, until it assumes a certain color, which indicates a certain degree of hardness. The gradations of the hues are a light straw, violet, blue, slate, and finally black. With this last color, the steel has become as soft as if it never had been hardened.

Several explanations have been offered of the changes in constitution through which the steel passes in the operations of tempering; but none of them are very satisfactory. It seems to be probable, says Ure, that the ultimate molecules are thrown by the sudden cooling into a constrained state, so that their poles are not allowed to take the position of strongest attraction and greatest proximity, and hence the mass becomes hard, brittle, and somewhat less dense. The more sudden the cooling of ignited steel, the more unnatural and constrained will be the distribution of its particles, and also the more refractory, an effect produced by plunging it into cold mercury. This excess of hardness is removed in any required degree by judicious annealing or tempering. The state of the carbon present in the steel may also be modified by the rate of refrigeration, as, Mr. Karsten and M. Breant conceive, happens with cast-iron and the damask metal. If the uniform distribution and combination of the carbon through the mass determine the peculiarity of white cast-iron, which is a hard and brittle substance; and if its transition to the dark-grey and softer cast-metal be effected by a partial formation of plumbago during slow cooling,—why may not something similar be supposed to occur with steel, an analogous compound?

Alloys of Steel.—A few years ago, a series of experiments were made both in this country and on the Continent, to combine steel with other metals, for the production of an alloy or superior quality of steel. These experiments tended to show that steel, combined with very small quantities of platinum, silver, rhodium, or iridium, was much increased in hardness; but no extensive practical application ensued.

Composition of Different Kinds of Steel.—The whole operations in the manufacture of iron and steel, and their relation to each other, form a subject of great interest, and one which requires a thorough investigation—not confined to isolated experiments, but embracing both practical skill and chemical knowledge. One thing apparently essential to the production of good steel, is pure iron; but still, when the various qualities of steel have been analysed, there appears something which suggests further inquiry. The following are a few of these analyses:—

The first was a steel manufactured from iron produced from an ore of carbonate of that metal and manganese; it is termed Brescia steel, and is celebrated for hardness and elasticity. It is made in Styria, and is much used for cutlery; and gave—

	Centesimally.
Iron,	98·06
Carbon,	1·94
Sulphur,	trace
Silica,	trace
Copper,	trace
	100·00

The second was made from common Swedish iron, smelted from magnetic iron ore, which often contains silica, titanium, and copper; it was converted into steel in England, and is termed common English cast-steel. It was composed of—

Iron,	97·90
Carbon,	1·72
Silica,	0·22
Arsenic,	0·07
Copper,	0·07
Manganese,	0·02
	100·00

The third was made from Dannemora iron, smelted from magnetic iron ores. The steel was made in Sheffield, and is called best razor steel. It is uniform and hard, very fusible, and will not bear much heat. It gave—

Iron,	93·80
Carbon,	1·43
Sulphur,	1·00
Silica,	0·52
Arsenic,	0·93
Antimony,	0·12
Nitrogen,	0·18
Manganese,	1·92
Loss,	0·10
	100·00

The iron in the fourth was obtained from spathose iron ore, containing lime, copper, sulphur, silica, and manganese. The steel was very tough, and known as Solingen or Siegen steel. It is admirably suited for swords. It gave—

Iron,	97·88
Carbon,	1·70
Sulphur,	trace
Silica,	0·04
Copper,	0·38
Tin,	trace
	100·00

The fifth and sixth were, like the first, made from Styrian iron which had been smelted from a carbonate of iron and manganese. Fifth is a very hard and brittle steel, and will not take a fine edge. The sixth is an inferior steel. They gave—

	5.	6.
Iron,	98·87	98·44
Carbon,	1·13	0·97
Sulphur,	trace	trace
Silica,	trace	0 50
Loss,	—	·09
	100·00	100·00

In comparing the composition of some of the malleable irons with No. 6, it would be difficult to say in what the difference consists, so far as the chemical composition is concerned. In wootz, or Indian steel, aluminium is found. As these different qualities of steel have each peculiar properties, rendering one more suitable for certain purposes than another, the question may be asked—Do these different properties depend upon the different impurities?

Mr. C. Binks, in a series of interesting experiments upon the manufacture and true composition of steel, has advanced suggestions of very great importance. His experiments were conducted upon iron, submitted to different reagents, at a full red heat, as in case-hardening, or in the cementation-process. His results were as follow:—

1. That a small rod of iron packed in boxwood charcoal in a closed porcelain tube, and kept at a full red heat for twelve hours, did not, after being tempered, show a hard steel surface, nor did it exhibit, under high and different degrees of heat, the play of colors peculiar to real steel. It still remained malleable iron;

2. But when atmospheric air is admitted to such an arrangement, in such quantity only as still to keep the carbon in excess, then, in the first instance, the surface of the iron, and, finally, if the time of contact be long enough, the whole of the iron is converted into steel.

3. That the application to the iron of nitrogen gas does not produce steel.

4. That neither does the application of carbonic oxide give steel.

5. That the application to the iron of a hydrocarbon—as when olefiant gas is passed through the tube, or when the red-hot rod is dipped into oil containing no nitrogen—does not produce steel;

6. But that the application of olefiant mixed with ammoniacal gas, or the application of gaseous cyanogen, produces steel, as does also the dipping of the hot metal into a nitrogenised oil or fat.

7. That the application of ferrocyanide of potassium, as has been so long known, gives steel.

8. That equally with the ferrocyanide does the application of simple cyanide of potassium result in the production of steel; therefore, it is not to the iron contained in the ferrocyanide that the steel-making property of the latter salt is due.

9. That potassa applied to the hot iron, or the keeping the hot iron in the vapor of potassium, does not yield steel.

10. That with iron of the kind that has so far been referred to and used, *id est*, commercially pure wrought iron, containing no material proportion of carbon, the application to it of ammoniacal gas, or of nitrate of ammonia, fails to produce steel;

11. But that the application of ammoniacal gas or chloride of ammonium to iron containing a considerable proportion of carbon, ninety-five to five, results in its conversion into steel.

These results tabulated, and the composition of the reagents expressed in chemical formula, will better exhibit the inevitable deductions to which they lead:—

1. $Fe + C$—in excess, every other element excluded, ... leaves iron.
2. $Fe + C$—in excess $+$ atmospheric air, ... gives steel.
3. $Fe + N$—nitrogen, ... leaves iron.
4. $Fe + C\,O$—carbonic oxide, ... leaves iron.
5. $Fe + H_4\,C_4$—olefiant gas, ... leaves iron.
6. $Fe + H_4\,C_4$—in excess $+ NH_3$—ammoniacal gas, ... gives steel.
7. $Fe + N\ C_2$—cyanogen, ... gives steel.
8. $Fe + K_2\,Fe\,Cy_3$—ferrocyanide of potassium, .. gives steel.
9. $Fe + K\,Cy$—cyanide of potassium .... gives steel.
10. $Fe + KO$—potassa, ... leaves iron.
11. $Fe + K$—potassium, ... leaves iron.
12. $Fe + NH_3$—ammoniacal gas, ... leaves iron.
13. $Fe + N\,H_4\,Cl$—chloride of ammonium, ... leaves iron.
14. $\frac{Fe + C}{95 \quad 5} + N\,H_3$—ammoniacal gas, ... gives steel.
15. $\frac{Fe + C}{95 \quad 5} + N\,H_4\,Cl$—chloride of ammonium, .. gives steel.

The conclusions drawn from these experiments are thus stated by the author:—

That the substances, by the application of which to pure iron it is converted into steel, all contain nitrogen and carbon, or nitrogen has access to the iron during the operation.

That carbon alone added or applied to pure iron does not convert it into steel.

That nitrogen alone so added or applied does not produce steel; but that it is essential that both nitrogen and carbon should be present, and that no case can be adduced of conversion in which both of these elements are not present and in contact with the iron.

That both nitrogen and carbon exist substantially in steel after its conversion; and the presence of both is the real cause of the distinctive physical properties of steel and of iron, in which latter these elements do not exist.

That presumptively, but not demonstratively, the form of combination is not that of cyanogen—though that compound plays so important a part in conversion—but is that of a triple alloy of iron, carbon, and nitrogen.

Lastly, that experimental research is yet required to determine the relative proportions of the elements when their union gives pure steel.

The reader will perceive that these investigations and their results are deeply interesting, and throw an entirely new light on the composition of steel. May not the nitrogen take the place of that portion of carbon which is eliminated from the cast-iron during the process of its conversion?

Passive State of Iron.—The curious property which iron exhibits of passing into what has been termed the *passive state*, may not be entirely without its effects upon the different conditions and combinations of this metal. It shows, at all events, that its molecules are easily thrown into a peculiar condition in relation to other bodies; as, for instance, if a piece of iron is put into nitric acid of specific gravity 1·3 to 1·35, it dissolves freely with effervescence; but if a piece of platinum wire be placed in the acid, and then the iron be introduced in contact with the platinum, the acid will not now act upon the iron, even if the platinum is withdrawn. Another piece of iron put into the acid in contact with the previous piece, will become affected in the same way; and so on with a third or with more pieces, so that this simple contact effects some important change in the molecular state of the metal. A great many other methods are known of making iron passive—by oxidising one extremity in the flame of a lamp; by making it the positive pole of a battery; by a blow; by previous immersion in concentrated nitric acid, *et cetera.* This peculiar condition can be easily annulled by rubbing the piece of passive iron, or bringing it into contact with active iron. These phenomena are not yet satisfactorily explained, and ought not to be overlooked in any investigation into the properties of iron, even with reference to its chemical applications.

ALLOYS OF IRON.—Cast-iron and steel, which are compounds of iron and carbon, with perhaps nitrogen, do not properly fall under the designation of alloys, which are compounds of two or more metals.

Iron combines, however, with several other metals, and forms alloys, some of which are interesting to the chemical inquirer; but few of them have much practical value.

With potassium iron forms an alloy, which is white, malleable, and so soft as to take impressions from the nails of the hand, oxidising easily in the air.

With the metals of the earths iron combines, and produces hard, white, and brittle alloys of no known value; but it appears capable of taking up only a small quantity of these metals.

Iron combines with titanium, which is often found with it in the products of the blast furnace; but it seems incapable of taking up any great quantity of that metal; for, although the two metals are fused together, they readily separate, and only a small portion of the titanium remains with the iron.

Iron and molybdenum form an alloy of a bluish-grey color, hard, brittle, fine-grained, and magnetic. When formed of equal parts of the two metals, this alloy is fusible before the blowpipe; but if formed of two parts of molybdenum and one part of iron, it is not so. The following curious and interesting analyses of pig-iron, containing molybdenum in quantity along with other metals, are taken from GMELIN'S *Handbook of Chemistry*:—

	I.	II.	III.	IV.	V.	VI.	VII.
Calcium,	—	—	—	—	—	0·29	trace
Magnesia and alumina,	—	—	—	—	—	—	trace
Manganese,	—	—	0·01	0·02	0·12	0·14	—
Iron,	57·91	73·26	74·60	76·77	73·11	81·14	50 to 80
Cobalt,	0·67	0·77	3·07	3·25	4·16	2·40	trace
Nickel,	3·42	4·63	1·28	1·15	0·84	trace	1 to 6
Copper,	2·45	1·79	4·32	3·40	5·34	7·69	2 to 4
Silver,	—	—	—	—	trace	—	—
Molybdenum,	28·49	9·13	10·19	9·97	5·28	0·08	10 to 30
Silica,	—	—	0·39	0·35	1·83	1·94	—
Carbon,	0·87	1·42	0·48	0·38	1·20	0·69	trace
Arsenic,	—	—	2·47	1·40	2·70	1·82	—
Phosphorus,	3·52	6·05	2·27	1·25	1·38	0·81	2 to 5
Sulphur,	0·60	0·09	0·92	2·06	2·94	0·62	trace
Loss,	0·07	2·86	—	—	1·10	2·38	—
	100·00	100·00	100·00	100·00	100·00	100·00	

I. Pig-iron from the upper works at Eisleben, obtained in the fusion of bituminous marl-slate in smelting furnaces; fine-grained.
II. Ditto; coarse-grained.
III. The so-called Magdeburg meteoric iron, containing slag mixed with bronze, yellow copper cinder, probably the pig-iron from a copper furnace; fine-grained sample.
IV. Ditto; coarse-grained sample.
V. The same substance, analysed by WEHRLE.
VI. Pig of iron found in the neighborhood of the *Rothehutte* in the Hartz.
VII. Pig of iron found underground at Sauchstadt.

Iron and manganese combine together, forming an alloy whiter and more brittle than iron; and when the proportion of manganese is about twenty-two per cent., the alloy ceases to have magnetic properties.—*Mushet.*

Arsenic and iron combine and form alloys of a white color, hard and brittle. When fifty-four parts of iron filings and one hundred and eight parts of arsenic are ignited together in a close vessel, they combine into an alloy which does not fuse, but is easily pulverised, and is composed of two equivalents of iron and one equivalent of arsenic.—*Gehlen.*

Iron and antimony, when heated together, fuse into a mass with combustion. When one equivalent of antimony and three of iron combine, they form a hard, brittle alloy, slightly magnetic, and having a density below the mean given by calculation. The alloy of one part of iron and two parts of antimony gives sparks when filed.

Iron and bismuth form a very brittle alloy. It is attracted by the magnet when the iron is only one-fourth of the bismuth.

Iron and zinc combine with difficulty, producing alloys that are very brittle.

Iron and lead do not readily combine. When slag containing lead and iron were reduced together, a brittle alloy was formed of a steel-grey color, and magnetic, composed in one hundred parts of—

Iron,	96·76
Lead,	13·24
	100·00

Iron and tin combine together in various proportions. Twenty-two parts tin and one part of iron give an alloy much harder than tin, and magnetic. Two parts iron and one part tin give a white, hard, and slightly malleable alloy, and difficult to fuse. In recovering the mercury used in silvering glass, an alloy of tin and iron is obtained, having the following properties:—Specific gravity, 8·733; brittle, and fuses at a white heat; when in powder, and put into the flame of a candle, it burns with emission of sparks and a white smoke; and does not rust when moistened with water and exposed to the air; it is composed of—

Iron,	57·86	57·9
Tin,	42·14	42·1
	100·00	100·00

being equivalent to Fe_3 Sn.

Nickel and iron combine and form a very hard alloy, which is that found in meteoric stones. Cobalt, copper, silver, gold, platinum, palladium, and other more rare metals, all combine in small proportions with iron, producing alloys of no known value in the arts.

STATISTICS.—The following table from a paper by Mr. KENYON BLACKWELL, on the Iron Industry of Great Britain, which was read before the Society of Arts a few years ago, gives the estimated production of crude iron in the principal countries of Europe at that period:—

	Tons.
Great Britain,	3.000.000
France,	750,000
United States,	750,000
Prussia,	300.000
Austria,	250.000
Belgium,	200.000
Russia,	200.000
Sweden,	150.000
Various German States,	100.000
Other countries,	300,000
	6,000.000

It will be seen, therefore, that Great Britain produces as much crude iron as all the other countries put together. The subjoined statement, extracted from the Mining Records, published under the direction of Mr. R. HUNT, in connection with the Museum of Practical Geology in London, gives the state of the manufacture in Great Britain in 1854:—

Counties.	Number of works.	Number of furnaces erected.	Number of furnaces in blast.	Total produce in tons.
ENGLAND:—				
Northumberland, Durham, and Yorkshire,	37	106	80	348,444
Derbyshire,	13	33	25	127,500
Lancashire and Cumberland,	2	5	3	20,000
Staffordshire,	72	203	166	847,600
Shropshire,	13	34	28	124.800
Gloucestershire,	4	7	5	21,990
WALES:—				
Flintshire, Denbighshire,	7	11	9	32,900
Glamorganshire—anthracite district,	14	35	21	750,000
Glamorganshire and Monmouthshire—bituminous district,	34	134	100	
SCOTLAND:—				
Ayrshire,	9	41	30	249.600
Lanarkshire,	13	88	72	468.000
Other counties,	10	27	16	79,040
	228	724	555	3,069,874

The importance which Scotland has assumed in reference to the iron manufacture, as shown in the preceding table, is well worthy of notice. This appears still more strikingly in tho following statement given by TRURAN for 1855:—

District.	Number of furnaces.	Mean weekly produce of each furnace.	Annual production of crude iron in tons.
South Wales,	169	118	1,042,776
Do., anthracite,	37	72	139,880
Dean Forest, North Wales, and Lancashire,	33	67	115,460
South Staffordshire,	169	108	948,520
North Staffordshire,	19	104	102,960
Derbyshire,	30	101	158,080
Shropshire,	34	86	151,720
Yorkshire,	31	72	116,480
Northumberland,	79	132	541,320
Scotland,	145	145	1,082,640
Total,	746	113	4,399,836

Sheffield and its neighborhood is the great seat of the steel manufacture. The annual quantity of steel produced during the last five years, says TOMLINSON, varies from sixteen thousand to seventeen thousand tons from foreign iron, and from one thousand five hundred to two thousand tons from iron of British manufacture. The number of converting furnaces is upwards of one hundred and twenty, each of which is capable of converting weekly six tons of iron; the coal consumed in the process is about equal to the weight of steel produced.

The cost of converting cast into malleable iron averages about three pounds per ton. Mr. TRURAN states that the conversion of Scotch pig-iron into bars is largely pushed in Wales; and that the bars so manufactured, after paying freight from and to Glasgow, undersell the produce of local manufactories of bar or malleable iron.

About three-tenths of the quantity of iron produced, says MACCULLOCH, is used in the state of pig or cast-iron, and is consumed principally in Great Britain and Ireland. The exports of pig-iron, however, amounted in 1850 to about one hundred and forty-two thousand tons, sent principally to the United States, Holland, Prussia, France, and British North America. The other seven-tenths are converted into wrought-iron, being formed into bars, bolts, rods, *et cetera.* The exports of bar-iron amounted in 1850 to nearly four hundred and forty-three thousand tons; and, during the same year, the exports of all sorts of iron reached the prodigious amount of seven hundred and eighty-three thousand four hundred and twenty-three tons, which, at seven pounds a ton, would be worth five million four hundred and eighty-three thousand nine hundred pounds sterling. And their declared value did in fact amount, in 1850, to five million three hundred and fifty thousand and fifty-six pounds sterling.

SALTS OF IRON.—It has been shown that iron is susceptible of two definite degrees of oxidisation, forming a protoxide—$Fe\,O$—and a sesquioxide—$Fe_2\,O_3$. Both these oxides are salifiable, giving rise to ferrous and ferric salts. The most important is the native *protocarbonate*, which constitutes the principal source of British iron, and has, therefore, been fully described in treating of the ores of this metal.

Protonitrate—$Fe\ O,\ NO_5$—is formed when very dilute nitric acid is digested upon iron filings; but is a very unstable compound, and passes into *pernitrate* by exposure to the air. The latter is a deep-red liquid, occasionally used in dyeing.

Protochloride—$Fe\ Cl$—results from transmitting dry hydrochloric acid gas over iron at a red heat, when hydrogen gas is evolved, and the surface of the iron is covered with a white crystalline protochloride. Also, by acting with hydrochloric acid on iron, evaporating to dryness, and heating to redness in a tube without exposure to the air. It dissolves freely in water, yielding a pale-green solution, from which rhomboidal prisms of the same color are obtained by evaporation. The aqueous solution absorbs oxygen from the air, and becomes yellow from the formation of sesquichloride.

Sesquichloride—$Fe_2\ Cl_3$—is formed by the combustion of iron wire in dry chlorine gas, or by transmitting that gas over iron moderately heated, when it is obtained in small iridescent plates of a red color, which deliquesce readily, and dissolve in water, alcohol, and ether. The readiest mode of obtaining it in solution, is to dissolve sesquioxide of iron in hydrochloric acid.

But the only salts of iron of great commercial importance are the *protosulphate* or *green vitriol*, and the double haloid salt, the *ferrocyanide* of iron, better known as *prussian blue.* To these the Editor will, therefore, confine his attention in what follows; but, in connection with the latter, it will be necessary to describe the preparation of another important salt, in which iron occurs as an element, the *sesquiferrocyanide of potassium,* known commercially as *prussiate of potassa.*

PROTOSULPHATE OF IRON.—Syn. Green Vitriol, Copperas; *Couperose verte,* French; *Eisenvitriol, Schwefelsaures Eisenoxydul,* German.—This salt, which has many important applications, is usually formed for medicinal and chemical purposes by dissolving iron filings or turnings in dilute sulphuric acid, filtering and evaporating the solution, and setting it aside to crystallize. The crystals are sea-green, transparent, rhomboidal prisms, and have a strong styptic inky taste. Exposed to dry air, they effloresce; in moist air, the salt gradually absorbs oxygen, and is partly converted into a sesquisulphate, becoming of a rusty or reddish color, whence the French term *couperose,* corrupted into the English name *copperas.* BONSDORFF has shown, that when perfectly pure it does not change vegetal blues, though generally stated to do so, the reddening effect being only produced when some of the iron of the protoxide passes into a higher state of oxidation. It is soluble in two parts of cold, and in three-fourths of its weight of boiling water. Crystallized protosulphate of iron contains seven equivalents of water, and is, therefore, represented by the following formula, $FeO,\ SO_3 + 7\ HO$. When heated, it fuses in its water of crystallization, and at 238° loses five equivalents of water, but retains one equivalent till heated above 535°. At a red heat, it evolves anhydrous sulphuric acid, and by this process sulphuric acid used formerly to be prepared; hence it was termed *oil of vitriol.* The residue, consisting of *peroxide* of iron, which remained in the vessel, was known under the name of *Caput mortuum vitrioli,* or *colcothar.* The fuming sulphuric acid is still prepared from the protosulphate in this manner.

The copperas of commerce is usually prepared from the pyritous schists of the coal measures, in connection with the manufacture of alum. By referring to the article on that subject—Vol. I., pp. 155-7—it will be seen that iron pyrites, or the bisulphide of iron—$Fe\ S_2$—is present in very large proportion in many aluminous schists, and that it is quite as indispensable to the production of alum as the alumina itself. When the schists are subjected to calcination in heaps, the sulphur of the bisulphide of iron absorbs oxygen from the air, by which it is converted into sulphuric acid, and this combines with the other ingredients, forming a sulphate of alumina and protosulphate of iron. These salts are extracted by lixiviation in the same waters; and therefore the next operation is to separate the iron salt from the aluminous, when both have been obtained in solution in the same vat. For this purpose the solution is evaporated in large cisterns, by carrying the flue of a furnace over its surface, and when sufficiently concentrated is run into coolers, where the sulphate of iron crystallizes, and the sulphate of alumina, being the much more soluble salt, remains in the mother-liquors. The process of separating the two salts by crystallization varies, however, in different manufactories, according to the quantity of sulphate of iron present; and the various methods adopted, with the nature of the changes that occur, will be found fully explained in the article already referred to.—See Vol. I., page 162.

The commercial article, prepared as above-described, is by no means pure; but generally contains a small proportion of alum, of the sesquisulphate, and other ingredients, some of which increase its value for particular purposes. In dyeing black, for example, that copperas is preferred which contains sesquisulphate, and is known by its darker green color. The excess of acid in some kinds of copperas is objected to; and those in which the crystals are small do not fetch so high a price as when the crystals are large. The following table, from Payen, indicates the composition of specimens from different French manufactories:—

		Paris.	Honfleur.	Noyon.	Forges.
Water,		47·5	48·7	48·40	46·60
Acid in excess,		3·4	1·5	—	—
Sulphate of	Protoxide of iron,	47·9	49·5	46·80	48·00
	Sesquioxide, soluble,	0·8	0·2	1·11	1·90
	Sesquioxide, insoluble,	0·3	0·1	0·19	0·95
	Copper,	—	—	0·99	0·35
	Manganese,	0·1	—	—	—
Alum,		—	—	2·51	2·20
		100·0	100·0	100·00	100·00

It will be observed from the preceding table that the copperas prepared at Paris and Honfleur is absolutely free from copper and alum, and is, therefore, of very great purity. This arises from the fact that in those localities it is prepared by the direct process, instead of obtaining it from the pyritous shales in connection with the manufacture of alum.

The original materials employed are iron turnings and shavings, obtained from establishments where such operations are conducted, and sulphuric acid of 18° or 23° Waddell, which is also a residue obtained from the rectification of certain lamp-oils. The acid is poured into rectangular copper vessels, strengthened by iron plates, and heated by means of a fire below, the flames of which play under and around the sides of the vessels. The iron turnings, previously sifted, are then introduced, agitating from time to time with wooden stirrers, and adding more turnings in proportion as they dissolve in the liquid. The oxidised portion of the iron dissolves directly; the more abundant metallic portion becomes oxidised by seizing on the oxygen of the water, and causing the disengagement of its hydrogen, mixed with different volatile products arising from the rectification of the oils and other organic matters. These gases and vapors are given off with the steam, and the liquid is maintained for eighteen to twenty hours in a state of constant ebullition, by which it is gradually more and more concentrated. The strong and offensive odor exhaled during this operation would greatly inconvenience the neighborhood, were not the precaution taken to cover the boiler with a hood, from which the gases and vapors are conveyed through a wide tube into a tall chimney creating a powerful draught.

When the concentration has reached its proper limit, which is known by observing the crystallization when some drops of the solution are put upon a plate of porcelain or earthenware, the liquid is drawn out with a pump constructed of copper, and flows by a gutter into a cellar, where it is left for a period of eighteen to twenty-four hours, to deposit the matters in suspension. The clear solution is then transferred by means of a siphon into sluices, by which it is conducted into other vats, measuring about seven feet in diameter, by three or four in depth.

These are the crystallizing vats. Planks are laid across them, pierced with holes, through which slips of wood are suspended vertically in the solution. The crystals which form on the sticks, and on the sides of the vat, are transparent, and exhibit the ordinary green color. At the end of eight or ten days, if the temperature of the air be not too high, the crystallization is finished; and the mother-water is made to flow out, to be conveyed back to the boiler along with the sulphuric acid and iron turnings. The sticks are taken out, and the crystals at the bottom, mixed with the deposited sediment of impurities, are taken to be redissolved. The crystals adhering to the sticks, and to the sides of the vat, are detached and rapidly dried, to avoid the formation of a rust-colored salt, which would tarnish the crystals. They are then put into barrels for the market.

Copperas is extensively used in dyeing black, especially for hats; in making ink and prussian blue; for reducing indigo in the blue vat; in calico-printing; and in many chemical and medicinal preparations. Its value as an ingredient in dyeing black, and in making ink, arises from the special reaction of the iron with the tannin contained in nut-galls, oak-bark, catechu, and different tinctorial substances. It promotes the solution of the indigo by a deoxidation of the coloring principle. On these applications, see the articles Dyeing and Ink. Copperas is used also for the decomposition of chloride of sodium in the fabrication of soda, and in making the *protoacetate of iron*, for which see Vol. I., page 41.

Sesquisulphate of Iron.—This salt—$Fe_2\,O_3.\,3\,SO_3$—is formed by mixing with a solution of the protosulphate exactly half as much sulphuric acid as that salt contains, and adding to the mixture in a boiling state successive portions of nitric acid until nitrous fumes cease to appear. The solution is then evaporated to dryness to expel the excess of nitric acid, and the sesquisulphate remains as a white salt. It is formed in the mother-waters of the protosulphate, and, according to Dumas, the two salts are capable of crystallizing together and forming a kind of double salt. It is this combination which imparts to much of the protosulphate of commerce a dingy grass-green color, whereas the pure sulphate of the protoxide furnishes hydrated crystals which are of a bright bluish-green.

Ferrocyanide of Iron.—Syn. Prussian Blue; *Bleu de Prusse*, French; *Berliner blau*, German.—This celebrated pigment was accidentally discovered by Diesbach, a color-maker at Berlin, in 1710, from which it became generally known as Prussian or Berlin blue. The first description of the mode of preparing it was given by Woodward in the Philosophical Transactions for 1724. It is a compound of iron and cyanogen, and, therefore, its true composition was unknown till the latter body was discovered by Gay-Lussac in 1815.

At common temperatures and pressures, *cyanogen* is a colorless gas, and has a penetrating and peculiar smell, somewhat resembling that of bitter almonds. It was so named by its discoverer, from two Greek words—*kuanos*, blue, and *gennao*, to produce—because it is essential to the formation of *prussian blue*.

It is composed of two equivalents of carbon and one of nitrogen; its formula is, therefore, $C_2 N$; its symbol is Cy, and its equivalent 26. It unites as a compound radical with oxygen, hydrogen, and most other non-metallic elements, and also with the metals. United to one equivalent of hydrogen, it forms *hydrocyanic* or *prussic acid*, which is, therefore, expressed by the formula $H\,Cy$, or $N\,C_2\,H$. In combination with iron, cyanogen forms a variety of double compounds, the composition of which is best explained by assuming the existence of a radical which contains one equivalent of iron in combination with carbon and nitrogen in the same proportion as they exist in cyanogen, but in such quantity as would form three equivalents of the latter, and which radical, by uniting with two equivalents of hydrogen, forms a bibasic acid. This hypothetical radical—$Fe + 3\,Cy$—is termed *ferrocyanogen*, and its symbol is Cfy; the acid—$Cfy + H_2$—is termed hydro-ferrocyanic acid; and the compounds of the radical with the metals are distinguished by the same adjuncts to ferrocyanide as are used for the corresponding oxides.

Prussian blue is regarded as a compound of three equivalents of ferrocyanogen with two of iron, and its composition is therefore expressed by the formula $3\,Cfy + 2\,Fe_2$, or $Fe_7\,Cy_9$. It is formed whenever a salt of sesquioxide of iron is added to a soluble metallic ferrocyanide. The usual method is to precipitate a solution of sesquichloride or sesquinitrate of iron by ferrocyanide of potassium; and in point of fact a very important part of its manufacture consists in the preparation of this latter salt, which will now be described.

Ferrocyanide of Potassium, better known as *prussiate of potassa*, may be viewed as a double cyanide of iron and potassium, $Fe\,Cy + 2\,K\,Cy$. It is prepared on a large scale by fusing substances which are rich in nitrogen, as horn, hoof, and dried blood, with carbonate of potassa, in *iron* vessels. The result of the fusion, at a red heat, is a dark-grey mass, which, when lixiviated with boiling water, yields a solution which the Germans call *blutlauge*, or *blood-lie*, and when this has been sufficiently concentrated, it affords, on cooling, crystals of *yellow prussiate of potassa*, which are composed as follows:—

	Centesimally.
1 Eq. cyanide of potassium,............	61·80
1 Eq. cyanide of iron,....................	25·47
3 Eqs. water,..............................	12·73
	100·00

The crystals are transparent, of a lemon-yellow color, and are found in large quadrangular plates or short prisms, with truncated edges and angles, which belong to the square prismatic system. They dissolve in four parts of cold, and in two of boiling water. They are permanent in the air at common temperatures, but at 212° lose their water of crystallization, without changing their form, and acquire a whitish color.

Ferridcyanide of Potassium or *Red prussiate of potassa*, is formed by passing a current of chlorine through a solution of the yellow prussiate, until a portion of the liquor, taken for trial, is found to give no precipitate with a salt of sesquioxide of iron. The solution is then filtered and evaporated *in vacuo* by means of sulphuric acid, when small acicular crystals of a garnet-red hue are obtained; and on purifying by successive crystallizations, the *red prussiate* is obtained in large transparent crystals, combining with a ruby-red tinge an almost metallic lustre. These crystals are anhydrous, and are composed of—

	Centesimally.
3 Eqs. cyanide of potassium,.............	59·20
1 Eq. sesquicyanide of iron,.............	40·80
	100·00

This salt—the formula of which is $K_3\,Cy_6\,Fe_2$—is formed by the abstraction of one equivalent of potassium from two equivalents of the yellow salt. The red salt is used in calico-printing, and both are employed in *de laine* printing, as well as in dyeing wool; the blue from the red prussiate being found more durable when fixed by binoxide of tin.

In most metallic solutions the two prussiates occasion precipitates of a characteristic color, which renders them of great importance in analytical chemistry, especially in qualitative analyses. In these reactions, the metal in solution takes the place of the potassium, and the resulting products are a soluble salt of potassa, and a double cyanide of iron and of the metal in solution, which, being usually insoluble, is precipitated.

With *protoxide of iron*, the red prussiate gives a dark-blue precipitate; the yellow prussiate, a white precipitate, which almost immediately becomes blue when exposed to the air.

With *sesquioxide of iron*, the red prussiate gives no precipitate; the yellow prussiate, a dark-blue precipitate, which is *prussian blue*—

	Centesimally.
3 Eqs. cyanide of iron,....................	46·00
2 Eqs. sesquicyanide of iron,............	54·00
	100·00

In the process which is usually followed for the fabrication of prussian blue, the product obtained has always a variable composition; because, instead of employing pure sesquioxide of iron, use is made of the sulphate of the protoxide or *green vitriol*, which is only partially converted into sesquisulphate, and still retains a greater or less proportion of protosulphate. This last gives, with the yellow prussiate, a white precipitate, which, as above stated, becomes blue by absorbing oxygen from the air, and forms a basic salt, which is distinguished from the true prussian blue by its solubility in pure water, giving it a fine blue color. This basic salt must not be confounded with another blue which is obtained by pouring slowly the sesquinitrate of iron into a solution of prussiate of potassa, keeping the latter constantly agitated. In this case the precipitate produced is partly soluble in pure water, which it colors a fine dark-blue. On evaporating the menstruum to dryness a brilliant residue is obtained, which has the appearance of a varnish, is almost completely soluble in water, and consists of a combination of neutral prussian blue with the yellow prussiate of potassa.

The insoluble prussian blue is found in lumps more or less compact, with a dull fracture, of a dark-blue color presenting a reddish reflexion, but assuming, when rubbed, a fine metallic bronze lustre, and altogether much resembling indigo. It is completely soluble in water and alcohol, and is not affected by dilute acids. Concentrated sulphuric acid converts it, in the cold, into a whitish pasty mass, which, when diluted with water, becomes decomposed, and gives a precipitate of prussian blue. Heated with concentrated sulphuric or nitric acid, it is completely decomposed, and the subsequent addition of water no longer produces a blue precipitate. Potassa, soda, and their carbonates, baryta, strontia, and caustic lime, precipitate the iron of its cyanide in the form of sesquioxide, and there is formed an alkaline or earthy cyanide, which combines with the cyanide of iron to constitute a soluble double salt. If, for example, potassa be employed, the yellow prussiate will be reproduced; and in point of fact this is the best process for obtaining that salt in a state of purity. When prussian blue is digested with red oxide of mercury and water, the blue color disappears; there is formed cyanide of mercury, which dissolves, and a clear brown precipitate remains, formed of cyanide and sesquioxide of iron.

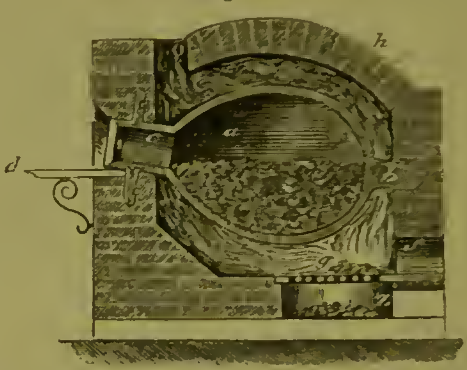
Manufacture of Ferrocyanide of Potassium.—This operation consists, as previously stated, in heating to redness nitrogenous organic matters, such as dried blood, horn, hair, skin refuse, and other offals, along with carbonate of potassa and iron. The animal matters may either be employed in the crude state, or after being subjected to a previous calcination. The latter method is generally adopted, because it permits of extracting, by a preliminary distillation of the nitrogenous substances, a considerable quantity of carbonate of ammonia, which may be converted either into chloride of ammonium, or directly into caustic ammonia—products of so much commercial value that prussian blue is generally a mere secondary product of the manufacture of ammoniacal salts.

All the residues of the calcination, or of the distillation of animal matters, are fitted for the fabrication of prussiate of potassa, with the exception of animal black, which, in consequence of the great quantity of phosphate of lime contained in it, would produce, by calcination with the carbonate of potassa, a corresponding quantity of phosphate of potassa instead of prussian blue.

The product of the preliminary calcination of the crude materials is ten to thirteen per cent. of animal charcoal, which is finely pulverized, and mixed very intimately with pearlash of good quality, as free as possible from sulphate, in the proportions of one and a half to two parts of charcoal to one part of potassa. The latter may be dissolved in the smallest possible quantity of water, which has the advantage of separating the foreign salts, and especially the sulphate—these being insoluble in a very strong solution of potassa; this concentrated menstruum is made into a paste with the charcoal powder, and the whole is then exsiccated. In this way the potassa is made to penetrate the pores of the charcoal, and the mixture is much more intimate than can be procured by any mechanical process.

The whole is then heated in a kind of retort, until brought to a state of pasty fusion, at which it is maintained. The retort employed is of cast-iron, very thick, somewhat varying in its shape, but which in all cases should have the mouth or neck rather narrow, to admit of being easily closed up. The form most generally adopted is represented in Fig. 314; the body of the retort, *a*, is ovoidal; it is supported at the back by a projection, *b*, which rests in the wall of the furnace; the neck, *e*, is cylindrical, and is kept firm in its place by two lateral projections, *c c*. The mouth of the retort is closed by means of the lid, *i*, and in front of the opening is the working plate, *d*, which consists of an iron or stone slab, supported externally by a bracket; *g* is the grate on which the fuel is introduced through the charging-door, *f*; *z*, the ash-pit; *h*, the vault of the furnace; and *o* the flue which conducts the products of combustion into the chimney.

Fig. 314.



The retort is about half-filled with the mixture above-mentioned, and at first it is heated gradually by charging the grate with fuel. As soon as the retort arrives at a red heat, the mouth is closed by means of the lid, *i*, and the fire is then kept up just sufficiently to maintain the same temperature. Every quarter of an hour the plate, *i*, is removed for an instant, in order to agitate the pasty mass as quickly as possible with an iron rabble. During this operation combustible gases are disengaged, which inflame at the mouth of the retort every time it is opened. The quantity of these gases diminishes as the process proceeds, and this is considered to be completed when all flame disappears. The first operation lasts, on the whole, about twelve hours, including in that period the time necessary to heat the furnace and the retort; the subsequent operations, when the mixture is introduced into the retort already heated to redness, require only eight hours.

An inconvenience which has not hitherto been satisfactorily overcome, and which considerably increases the price of prussiate of potassa, is the circumstance that the iron which enters into its composition is supplied at the expense of the retort itself. The lower part of the vessel is thus worn away, and often very unequally, so that it breaks out into holes. Hence it is necessary to give it in the first instance a thickness of one or two inches, and this requires that, in order to produce in the interior of the retort a suitable temperature, the furnace be heated to a bright red, which rapidly consumes the outside of the retort. Attempts have been made to add directly to the mixture of animal charcoal and potassa, iron very finely divided in the shape of filings or turnings, but not hitherto with that success which was anticipated. When a hole appears in the lower part of the retort, it is turned half round on its axis, the hole is stopped up with iron cement, and the retort is thus made to serve for a new series of operations.

When the fusing processs is completed, the molten mass is scooped out with an iron shovel, having a long handle, and is thrown into an iron pan, in which it is shut up and left to cool. The soluble matters are then thoroughly drained out with boiling water, and filtered through woollen cloths. The animal charcoal which remains upon the filter, possesses the property of decoloring sirups, vinegars, *et cetera*. It may also serve, when mixed with fresh animal charcoal, for another calcining operation. The clear yellow solution which passes through the filter, may either be employed directly for the preparation of prussian blue, or concentrated to the proper degree in iron boilers, and then introduced into wooden crystallizing vessels. The yellow prussiate thus obtained has still to be februated by one or two subsequent crystallizations before being sent into the market. In consequence of the great solubility of prussiate of potassa, the mother-water, or the liquid that remains after crystallization, still retains a notable quantity of that salt, together with carbonate, phosphate, and sulphate of potassa, as also the chloride, sulphide, and sulphocyanide of potassium. It is therefore employed for the direct preparation of an inferior quality of prussian blue, or concentrated by evaporation to extract from it an impure prussiate of potassa.

Mr. Muspratt of Liverpool, the founder of the British *alkali* trade, was one of the earliest to manufacture the yellow prussiate, which he did in Dublin in the years 1819, 1820. He found it very difficult to obtain the salt in large crystals; but this object he surmounted by mixing with every dissolved metal of prussiate one pound of sulphate of iron. The result proved most satisfactory. He was the first to use the copperas for this purpose. It is now employed often, and is further dwelt on below.

The theory of this manufacture is as follows:—The animal charcoal consists essentially of carbon, and contains, besides, a small quantity of nitrogen; when it is heated *per se* it undergoes no alteration, but when mixed with potassa and heated to redness, the affinity of the alkali for cyanogen determines the formation of the latter by means of the nitrogen and a part of the carbon contained in the animal charcoal. When, in addition to potassa, iron enters into the mixture, there is formed cyanide of iron, which, having a great affinity for the cyanide of potassium, combines with it to form a double cyanide, which is the prussiate of potassa.

Almost always, especially when the operation is arrested a little too soon, there is not a sufficient quantity of cyanide of iron formed to saturate the cyanide of potassium, which is then present in excess, and passes into the solution. To transform this excess of cyanide into ferrocyanide, before crystallizing the solution, a quantity of dissolved protosulphate of iron is poured in until a white or bluish and persistent precipitate begins to be formed. In this reaction, a part of the cyanide of potassium is decomposed; there is formed on the one hand sulphate of potassa, and on the other cyanide of iron, which combines with the undecomposed cyanide of potassium to form an additional quantity of the yellow salt.

Dr. Ure remarks that, all things considered, the manufacture of prussiate of potassa is perhaps less understood, and therefore less perfect than that of any other chemical substance of equal importance. Whether the primary materials be calcined or not, a prodigious waste invariably occurs in the manufacture, and fully two-thirds of the nitrogen existing in the animal matters are driven off and lost. More frequently, indeed, the loss amounts to three-fourths, and even this is sometimes exceeded. Woollen rags or clippings, and good American potassa or pearlash, *with an admixture of scrap-iron*, are stated by Dr. Ure to have given a larger produce than any other substances within the range of his experience, though, even in this instance, two-thirds of the whole nitrogen passed away as ammonia. In general one ton of dried blood or woollen rags, with about three hundredweight of good potassa, will produce from two to two and a half hundredweight of prussiate of potassa, and a proportionate amount of sulphate of potassa. The presence of scrap iron in a proper state of subdivision, is, however, necessary to insure the above result; for when no more is supplied than that which arises accidentally from the iron pot in which the operation is carried on, scarcely half these proportions will be obtained.—*Ure.*

In 1840 a patent for an improved method of conducting the manufacture of this important salt, was taken in the name of Mr. Berry, with a special view to avoid the loss of nitrogen incurred in the common process. For this purpose the primary matters are treated differently, so as to collect the nitrogen which escapes during the distillation, and to cause it to enter into combination with carbon, iron, and potassium—the carbonate of ammonia being made to pass through a mixture of these substances placed in iron pipes which are maintained at a red heat. The following proportions of ingredients have been found to give good results:—

	Parts.
Potassa,	30
Nitre,	10
Acetate of iron,	15
Charcoal or coke,	45 to 55
Dried blood,	50

The blood or animal matter is put into an iron vessel resembling a gas retort, and the other materials, mixed and dried, are put into vertical pipes with which the retort communicates. The pipes containing the absorbing mixture must be raised to a red heat before the retort containing the animal matter is heated, in order that from the commencement of the operation the decomposition of the gases may take place. The charcoal in the mixture decomposes the carbonate of ammonia which passes over, and forms bicarbide of hydrogen; at the same time it gives up part of it to the nitrogen which proceeds from the decomposed ammonia, and thereby forms cyanogen, which, in its turn, combining with the reduced potassa, forms ferrocyanide of potassium. To obtain the most complete reaction, the charcoal should be reduced into pieces of the size of a walnut, and soaked with a solution of carbonate of potassa in urine; the solution of nitrate or acetate of iron is then poured over the heap, and when the whole has been dried by a moderate heat, it is introduced into the pipes. The gas evolved by the decomposition is inflammable when issuing from the pipes, which are fitted with gas-burners, and the color of the flame indicates the progress of the operation. When it approaches to pink, it is known that the reaction is almost complete, and that very little if any ammonia has escaped decomposition. When the jet becomes smaller and clearer, and there is a good fire under the retorts, the operation is nearly terminated. The charge must then be removed; and being at a red heat, it should be at once thrown into water in order to extinguish it rapidly, the whole being well stirred and allowed to settle. The clear liquor is then drawn off, and the residuum is subjected to successive washings by filtration. The strong solutions are evaporated and crystallized, and the prussiate is extracted according to the old process. The weaker solutions, which will not crystallize, contain carbonate of potassa; and this is extracted to be employed in the next operation, along with the residuum of charcoal and iron mixed with fresh materials.

Fig. 315.

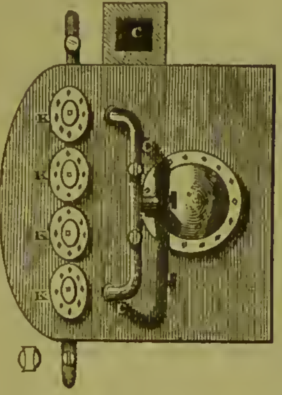
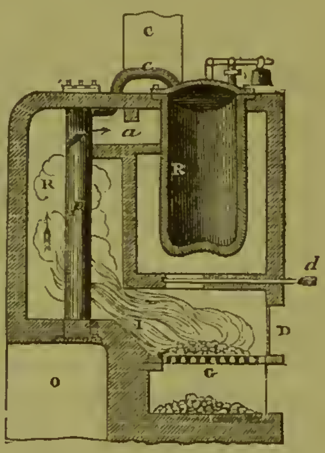


Fig. 316.



The apparatus in which these operations are conducted, is shown in different sectional views in Figs. 315, 316, 317, and 318, in all of which the same letters refer to the same parts. Fig. 315 is a top view of the apparatus. The general arrangement is exhibited in Fig. 316, where D is the door and G the grate of the furnace, R the retort containing the animal matters, and P one of the pipes containing the absorbing mixture. The number, the elliptical form, and the vertical position of the pipes, are shown in the other figures. The form of the tube, *c c*, by which they are connected with the retort, is represented in Fig. 315, and also in Fig. 317 with its stopcocks, *s*, *s'''*. I is an incline over which the flame passes to heat the pipes before it is permitted to play upon the bottom of the retort by withdrawing the slide, *d*. The products of combustion escape by a lateral passage into the chimney, C. In Fig. 317 are shown the gas-burners, *g*, *g'*, with their stopcocks, *s*, *s''*. K K, Fig. 315, are covers closing the pipes. Lastly, O, Fig. 316, is an open shed or roofed space under which the pipes are emptied at the end of each operation.

Fig. 317.

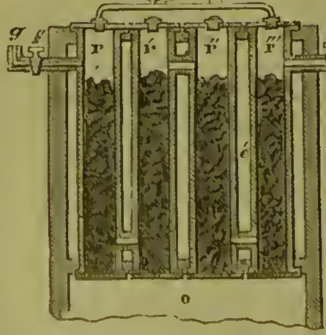
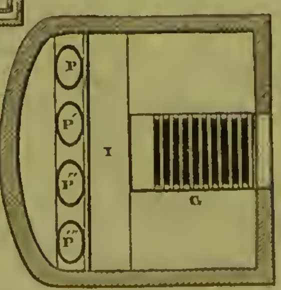


Fig. 318.



The most extraordinary event in the history of this manufacture, says GRAHAM, the writer of the Great Exhibition Jury Report on the prussiates of potassa, is the attempt made a few years ago to introduce the air-process, which is of much interest both in a scientific and practical point of view. As cyanogen is rapidly converted into ammonia, the artificial formation of the former from the nitrogen of air would likewise furnish an unlimited supply of ammonia, of which the importance to agriculture could not well be over-estimated. An account of the operations which were undertaken with this view, was communicated to Professor GRAHAM by Mr. F. R. HUGHES of Borrowstowness; who states that, in 1844, his firm commenced a series of experiments upon the large scale at Newcastle, in company with Messrs. BRAMWELL, to manufacture the ferroprussiate of potassa without animal matter, substituting the nitrogen of the atmosphere for it, and continued the experiments at very great expense till the latter end of 1847. In these operations a tube or retort of fire-clay was placed in a vertical position in a furnace capable of producing an intense heat. The tube was filled with wood-charcoal, saturated with a solution of the carbonate of potassa of commerce, and dried. The mixture in this state generally contained about twenty per cent. of potassa. By means of an air-pump, the atmospheric air was drawn through the tube of alkalized charcoal in a continuous stream from the top, and discharged below in the state of nitrogen and carbonic oxide. The alkalized charcoal was thus found to become pretty rich in cyanide of potassium: one half of the alkali of the cyanized charcoal frequently being found, upon testing, to be in combination with cyanogen; so that when all was working well, thirty-six to forty hundredweight of prussiate of potassa were produced in a week by means of seven to eight retorts, of ten to twelve feet long in the fire, and two feet internal diameter.

There were two great drawbacks to this process; one, the immense quantity of material to be lixiviated for a small return of prussiate; the other, and by far the more important, an extraordinary waste of potassa in the process, upwards of three parts by weight being consumed in producing one of prussiate. The whole of this waste could never be properly accounted for. About one part was, of course, recovered in a state of prussiate. It was found that another was lost in the small refuse charcoal, which could not be lixiviated to pay, and the remainder appeared to be partly combined with the bricks of the retort, and partly dissipated up the chimney.

In 1847 the experiment was abandoned after a loss of many thousand pounds; but it proved the possibility of producing large quantities of cyanide of potassium, by drawing intensely-heated nitrogen and carbonic acid gases through a mixture of potassa and charcoal, with the difficulty of carrying this out as a manufacturing process, from the great waste of potassa.

Preparation of Prussian Blue.—The theory of the fabrication of prussian blue has been already stated; it only remains to enter into some practical details on this subject.

A distinction is made between the pure or *Paris blues*, and those that are mixed with alumina, or *Berlin blues*. The choice of the original raw materials naturally depends on the beauty and price of the article which is intended to be manufactured. For the finer kinds, one employs prussiate of potassa which has been purified by several successive crystallizations; for the common blues, the crude solution of prussiate of potassa is almost always taken; lastly, for inferior varieties, the mother-waters of the manufacture of the crystallized prussiate are used.

The salt of iron almost exclusively employed is the protosulphate. It should not contain copper, which would give rise to a reddish-brown precipitate very injurious to the color of the prussian blue. The presence of copper is easily detected by dissolving in water a little of the sulphate for trial, acidulating the liquor with sulphuric acid, and dipping into it a well-cleaned plate of iron; if copper is present, it will be reduced, and will form a red metallic coating on the surface of the iron plate. Cupriferous protosulphate may be purified, and all the copper precipitated, by dissolving it in water, and boiling it for some time with a little sulphuric acid and old scrap-iron or turnings; but this process entails considerable expense, and it is better in all cases to procure sulphate of iron which is sent into the market free from copper—a precaution attended with little difficulty. Before employing this sulphate, it is left exposed to the air till it acquires a reddish-brown color. Perhaps it would be still better to employ for the preparation of the finest blues sesquinitrate of iron, which furnishes a blue of such great beauty that the additional expense incurred in its manufacture would be more than compensated by the quality of the product obtained.

The crude solution of prussiate of potassa, and even the prussiate purified by a single crystallization, still contain, as has been stated, more or less carbonate of potassa, so that, besides the prussian blue, there is precipitated at the same time yellow oxide of iron, which deteriorates its tint. To obviate this inconvenience, the carbonate of potassa is neutralized by sulphuric acid, which may be added either to the solution of prussiate of potassa or to that of the protosulphate of iron. In the manufacture of the common Berlin blues, the carbonate of potassa is neutralized by alum; there results a precipitate of alumina, which mixes intimately with the prussian blue, and greatly augments its weight without notably weakening the tint when the quantity is not very considerable. For this purpose, the requisite quantity of alum, previously determined by experiment, is dissolved in the solution of sulphate of iron; then the whole is poured little by little, and taking care to agitate continually, into the solution of prussiate of potassa, which gives a precipitate of a more or less dark blue that soon settles down. The supernatant liquid is then decanted, its place is supplied by pure water, it is again shaken, allowed to deposit, decanted, and is thus subjected to a series of successive washings, in order to abstract the soluble matters, and to deepen the color of the blue by the absorption of the oxygen contained in the water. The residue of the washing is then thrown on cloth filters, where it is left to drain; it is afterwards subjected to moderate pressure, and finally divided into small bricks or cakes, which are left to dry in the shade.

As prussian blue, when once dried, is difficult to reduce again to the state of extreme division which it possessed in the moist state, it is often sold and employed *in paste*—that is to say, *not dried*—especially for the manufacture of paper-hangings, *et cetera.*

A good article, says the late Dr. URE, is known by the following tests:—It feels light in the hand, adheres to the tongue, has a dark lively blue color, and gives a smooth deep trace; it should not effervesce with acids, as when sophisticated with chalk; nor become pasty with boiling water, as when adulterated with starch. The Paris blue, prepared without alum, with a sesquisalt of iron, displays, when rubbed, a copper-red lustre, like indigo. Prussian blue, degraded in its color by an admixture of free oxide of iron, may be improved by digestion in dilute sulphuric or hydrochloric acid, washing and drying. Its relative richness in the real ferrocyanide of iron may be estimated by the quantity of potassa or soda which a given quantity of it requires to destroy its blue color.

The precipitate formed by adding a solution of ferridcyanide of potassium—the red prussiate—to a protosalt of iron, constitutes the color known in commerce as *Turnbull's blue.* It is produced by the substitution of three atoms of iron for the three of potassium in the red salt. Its color is a little brighter than common prussian blue. It is prepared in the arts by adding to a solution of copperas a mixture of yellow prussiate of potassa and chloroxide of sodium.

Prussian blue is employed as a water color, but not in oil-painting. In 1837, Messrs. STEPHEN and NAX of London took out a patent for a process by which it can be obtained in solution, and employed not only in calico-printing, but also as a tinctorial agent, thereby greatly extending its application. The process consists in first digesting the prussian blue of commerce, for a period of twenty-four to forty-eight hours, with concentrated hydrochloric or sulphuric acid, and afterwards diluting the mixture with its own weight of water. It is then carefully washed, by decantation, with pure water, in order to remove all the acid; and, after being washed a second time on a filter, the residue is dried, and brayed in a mortar with oxalic acid. The resulting compound is found to be soluble in water.

The insufficiency of the description of this process which is given in the specification, and the absence of details with reference to the quantities of the materials to be employed, and the precautions necessary in the manipulation, induced M. KARMARSCH, a few years ago, to institute a series of experiments on this subject leading to the following results:—

1. The preliminary treatment of the prussian blue with hydrochloric or sulphuric acid, is attended with the advantages of requiring a much smaller quantity of oxalic acid to render the blue soluble; of causing the blue to keep longer without depositing any precipitate, which infallibly happens when it has not undergone the preliminary treatment; and, lastly, of rendering the blue soluble in a much smaller quantity of water, which permits of obtaining a more concentrated solution.

2. The quantity of oxalic acid necessary to determine the solution of the prussian blue is small; an excess of this acid, instead of increasing, diminishes its solubility in water.

3. The combination of prussian blue and oxalic acid is not soluble in water in all proportions; when the quantity of water is not sufficient, a portion of the color remains undissolved in the form of a dark-blue slime.

4. The most suitable proportions for obtaining a concentrated soluble blue, susceptible of being filtered without residue, and of keeping a long time without giving any deposit, are—eight parts of prussian blue treated with sulphuric acid, then well brayed with one part of oxalic acid, and dissolved in two hundred and fifty-six parts of water.

Physiological Effects.—Iron is probably inert, or only acts mechanically, so long as it retains its metallic form; but it readily oxidises in the alimentary canal, and thereby acquires medicinal power. As acids promote this chemical change, acid wines and fruits assist in rendering the metal active, while alkalies and their carbonates have an opposite effect. The oxidation of the iron is attended with the evolution of hydrogen gas, which gives rise to unpleasant eructations. If sulphur be taken along with iron, sulphide of hydrogen is developed. Like the ferruginous preparations generally, the internal employment of iron causes blackening of the stools, owing to the formation of the hydrated sulphide of iron. It is interesting to remark here, that iron is one of the few metals which by oxidisement *is not rendered more or less poisonous.*

The *local* effects of the sulphate, nitrate, and sesquichloride of iron, are those of caustics and irritants, and these preparations accordingly rank amongst poisons.

Most of the ferruginous preparations are astringent; that is, they constringe the parts with which they are in contact, and thereby diminish secretions and check sanguineous discharges. Thus, when swallowed, they repress the secretions and exhalation of the gastro-intestinal membrane, and thereby render the alvine evacuations more solid, and even occasion constipation. The sulphate, nitrate, and sesquichloride of iron, are the most powerful of the ferruginous astringents. Administered in large quantities, or when the alimentary canal is in an irritable condition, all the compounds of iron are liable to excite heat, or weight and uneasiness at the præcordia, nausea, and even vomiting, and sometimes purging. The oxides and the carbonate of iron are very mild topical agents.

Before the chalybeates can produce constitutional effects, they must become absorbed. Under their use the blood frequently acquires a more scarlet hue, owing to an increase in the number of its coloring particles. TIEDEMAN and GMELIN have detected it in the serum of the blood of the portal and mesenteric veins of horses and dogs, to whom they administered either the sulphate or chloride. Occasionally, too, iron has been found in the urine.

The constitutional effects of iron are best observed in anæmia. If, in this condition of system, chalybeates be administered, the appetite increases, digestion is promoted, the pulse becomes fuller and stronger, the skin assumes its natural hue, the lips and cheeks become more florid, the temperature of the body is augmented, the œdema disappears, and the muscular strength is greatly increased. These results are mainly due to the alteration in the composition of the blood. This is shown by the healthy vermilion tint which the patient acquires, as well as by the chemical analysis of the blood.

Iron filings are employed as an antidote in poisoning by the soluble salts of copper and mercury. The iron reduces them to the metallic state. The following formula explains the action of iron on a solution of sulphate of copper:—$Cu\,O,\ SO_3 + Fe = Cu + Fe\,O,\ SO_3$.

Sesquioxide of iron is termed alterative, tonic, and emmenagogue. Its obvious effects on the body, however, are very slight.

Hydrated sesquioxide of iron has been employed as an antidote in poisoning by arsenious acid, a basic insoluble arseniate being formed. BUNSEN and BERTHOLD were the first to assert the antidotal powers of this preparation. Their statements were confirmed by the experiments of SOUBEIRAN and MIQUEL, of ORFILA and LESNEUR, *et cetera.*

Sulphide of iron in cutaneous maladies of a scrofulous character has proved a valuable alterative, and more serviceable than iodine. It appeared to be less irritating, and not so liable to excite suppuration in scrofulous swellings. BIETT gave it in obstinate lichen agrius.

Sulphate of Iron.—This salt acts locally as a powerful astringent, and when employed in a concentrated form, as an irritant. The latter effect depends on its chemical action on the organic constituents, albumen, *et cetera*, of the tissues. The remote effects of sulphate of iron are analogous to those of other ferruginous compounds, which have been already described.

Swallowed *in small doses*, it has an astringent operation on the gastro-intestinal mucous membrane, and thereby diminishes the quantity of fluids secreted or exhaled; hence its continued use causes constipation. It blackens the stools like other compounds of iron. It becomes absorbed, and operates on the system as a tonic, stimulant, emmenagogue, and astringent. *In excessive doses* it acts as an irritant poison. A girl took, as an emmenagogue an ounce of it in beer, and was seized in consequence with colic pains, constant vomiting, and purging for seven hours. Mucilaginous and oily drinks soon cured her.

It is employed in lump, powder, or solution, as a styptic to check bleeding from numerous small vessels. The sesquinitrate, acetate, iodide, citrate, *et cetera*, are employed daily in medicine also. Their effects are similar to the other ferruginous salts.

The general indications for the use of the iron compounds are debility, feebleness, and inertia of the different organs of the body; atony, marked by a soft, lax, or flabby condition of the solids; and defect of the red corpuscles of the blood; as where there is a general deficiency of this fluid—*anœmia; oligœmia*, or a watery condition of it—*hydrœmia, serous crasis; leucophlegmatic temperament.*

The contra-indications are the reverse of these; great strength and activity of organs, excessive tonicity, characterized by a firm and tense condition of the solids, and redundancy of the red corpuscles of the blood,—as in general excess of the blood-plethora, in fever, in acute inflammation, in the sanguine temperament. To these may be added congestion, or a tendency thereto, of important organs—especially of the brain and lungs—and intestinal irritation.—*Pereira.*

Statistics.—At the Great Exhibition, the prussiates of potassa, which invariably accompany the manufacture of prussian blue, were exhibited of great purity and beauty, by several manufacturers, particularly Messrs. T. BRAMWELL and Company, of Newcastle; the Hurlet and Campsie Alum Company, of Glasgow; the Bouxwiller Mining Company, of France; C. SCHLIPPE, of Russia; and ALEXANDER BRUSGHIN, also of Russia.

The prussiate made by Mr. MUSPRATT in 1820, in Ireland, and that manufactured in England, sold for five to six shillings the pound; but for some years previously a weak solution of the salt, or of the fluxed mass of animal matter and potassa, had been sold at one shilling per gallon. The process of manufacture, so far as regards the materials used and the furnaces employed, is still essentially the same as it was fifty years ago; but in consequence of agitating the fluxed mass by machinery in closed pits, introduced at Glasgow by the late CHARLES MACINTOSH in 1824, and other minor improvements in the manipulation, the production of prussiate from the same quantity of animal matter has been increased threefold. The rapid progress of this manufacture will appear from the following estimate of the annual production in the United Kingdom:—

ANNUAL PRODUCTION.

From	1825—1830	about	10 tons	at	5s. 0d.	per pound.
"	1830—1835	"	40	"	2s. 6d.	"
"	1835—1840	"	200	"	1s. 4d.	"
"	1840—1845	"	700	"	1s. 4d.	"
"	1845—1850	"	1040	"	1s. 3d.	"

There are eleven prussiate works in the United Kingdom, of which the aggregate produce is, when the salt is in demand, about twenty tons per week. The two largest factories are those of Messrs. BRAMWELL and the Hurlet and Campsie Alum Company. The value of the annual product is estimated at one hundred and forty-five thousand six hundred pounds sterling.

The manufactory of Messrs. BRAMWELL was established about eighty years ago, at which time prussian blue only was made in it, a considerable quantity of which was sent annually to China, and used by the Chinese, it was believed, for coloring green teas; a Spring shipment was always made of about two thousand pounds sterling in value, which was often followed by another in Autumn. It was first sold at two guineas per pound, made up in neatly finished one-pound packages, but had fallen in 1815 to ten shillings and sixpence, and about 1820 to two shillings and sixpence. For the last ten or fifteen years the price of prussian blue has averaged one shilling and ninepence per pound.

The Editor begs to express his thanks to Mr. GEORGE BLAIR of Glasgow, for his kind assistance in the compilation of this and other articles.

LEAD.—*Plomb*, French; *Blei*, German; *Plumbum*, Latin.—This metal is of a bluish-grey color, with a strong metallic lustre when recently cut; but when exposed for a short time, its brilliancy disappears, and gives place to a very thin coating of basic carbonate of the oxide of lead. Owing to its softness it leaves a streak on white paper, and may be easily cut with a knife. It is highly malleable and ductile, but is deficient in tenacity, when compared with all the other ductile metals; a wire one-tenth of an inch in diameter being capable of supporting a weight of only thirty pounds. It may be easily rolled out into moderately thin sheets and likewise drawn into wire; but from its want of tenacity, the latter operation cannot be performed so freely as with gold, platinum, silver, copper, or iron. The specific gravity of lead is 11·445 when subjected to pressure, as in rolling; but in mass it is somewhat less, being 11·350; its chemical symbol, is *Pb*—derived from the Latin term *plumbum*—and its combining equivalent 104.

HISTORICAL NOTICE.—In the articles on COPPER and GOLD it has been stated that these metals were brought into use at a very early date, and it seems probable that *lead* was known at least as early as copper. Mention is repeatedly made of this metal in the book of Exodus, and in various other parts of holy writ. It would appear from BECKMANN, indeed, that some doubt exists as to the true meaning of the word rendered *lead* by the translators of the scriptures, although he does not deny its very great antiquity. The Phenician colony in Spain drew largely upon Britain for this metal, and also for tin; and it is stated by CAMDEN that lead was obtained from Cornwall, Cumberland, and other places in England, before the Christian era. During the incursions of the Romans, it is certain that it formed an important article of commercial interest; and that it was used in considerable abundance, may be inferred from the specimens which have been discovered from time to time, bearing Latin inscriptions. After the departure of the Romans, the Saxons continued to work the lead mines, one of which, near Castleton, was dedicated to Odin. That the mines near Wirksworth were worked before the year 714, appears from the discovery of a sarcophagus of lead, lined with linen prepared in that locality. In the year 835, the lead mines of Wireesworth were surrendered to one

HUMBERT, on payment of an annual rent in that metal to the value of three hundred shillings, for the use of Christ Church, Canterbury. In Doomsday-book the mines in the Peak, and the Wapentake of Wirksworth, are referred to as the peculiar property of the sovereign, and those of Derbyshire, were designated *The King's Field.* In the ages of alchemy, lead was regarded as a semimetal, and bore the name of *Saturn*, owing probably to its bluish-grey color.

SOURCES.—Lead is found in various combinations in mineral strata, and on rare occasions in the native state. Kerry in Ireland, Carthagena in Spain, and Alston Moor in Cumberland, have afforded specimens of lead in this state, sometimes associated with galena, and at other times disseminated therewith in an argillaceous or a silicious rock.

The ores of lead are numerous, but are found in very unequal proportions; that from which the metal is extracted being for the most part galena, or bisulphide of lead. The most important of them are the oxide of lead or massicot, chloride of lead, bisulphide of lead or galena, carbonate, phosphate, sulphate, arseniate, and chromate of lead.

Oxide of lead may be regarded as being derived from the sulphide in the presence of other bodies which exhibit an affinity for the sulphur. It is found only in small quantities, and usually associated with galena.

Chloride of lead is another very rare natural combination, which is found in small quantity in the Mendip hills, generally deposited upon a matrix of binoxide of manganese, and crystallized in rectangular prisms, with the angles and edges sometimes truncated.

Carbonate of lead—sparry lead ore—is remarkable for its transparency and lustre when in its purity. Several varieties of this ore are known. It is found in the form of acicular crystals, in compact masses, and often presenting a fibrous, lamellar, and earthy appearance. They all, with the exception of the earthy species, possess a peculiar lustre, like that of white lead. Earthy carbonate of lead presents several shades of color—brown, green, or blue—dependent upon the nature of the metal associated with it. The mineral is very brittle, and its fracture has a waved conchoidal appearance. Its specific gravity varies from 6 to 6·7.

It is met with in comparatively small quantities and is confined to a few localities. At Leadhills and Wanlockhead, two well-known Scotch localities yielding this metal, the carbonate occurs with other minerals, particularly with phosphate, sulphate, and other combinations of lead, accompanying galena in transition-slate. It occurs in the mines at Alston Moor, at Keswick, and in some parts of Cornwall, particularly at the mine of St. Minvers. In many of the continental mines, particularly in Saxony and the Hartz, it is eviscerated. Being a mineral rich in lead, it is easily smelted. A black species of carbonate of lead is sometimes found, which owes its characteristic color to small particles of galena being disseminated throughout the crystals. The most extensive deposit of carbonate hitherto discovered is that at the mine à la Motte, Missouri, in America, where millions of pounds of metal have been extracted from this mineral. When treated before the blow-pipe on charcoal, it decrepitates and changes color to a yellow, then becomes red, and finally is reduced to metal in the inner flame, the charcoal being coated with litharge. Heated with fluxes it gives rise to a diaphanous glass. Acids readily act upon it; carbonic acid being evolved with effervescence, and a lead salt of the acid being produced.

The following analyses have been made of this mineral:—

	Crystals of carbonate of lead from			
	Lead Hills Klaproth.	Zellerfeld Westrumb.	Nertschinsk. John	T J A
Protoxide of lead,...	82·00	81·20	84·5	[illegible]
Carbonic acid,......	16·00	16·00	15·5	16·
Lime,............	—	0·90	—	—
Iron,............	—	0·30	—	—
Loss,............	2·00	1·60	—	—
	100·00	100·00	100·0	[illegible]

The formula by which its composition may be expressed is $PbO\ CO_2$.

Sulphate of lead is a mineral associated with carbonate in the mines of the Leadhills and Wanlockhead in Dumfries-shire, Scotland. It is found in quantities in Parry's Mine in Anglesea, and at Mellanoweth in Cornwall, where it is associated with galena, from which it gives evident indications of being produced by oxidation. Sulphate of lead has been found at Clausthal and Zellerfeld, in the Hartz, and various other mines on the Continent; although the quantity is too small to attract the attention of the metallurgist.

Its color is sometimes grey or yellowish, frequently tinged blue or green by oxide of copper; its crystallized form is that of a rhombic prism, with dihedral summits: but when the crystals are short, they assume the form of the octahedron. Generally the crystals are possessed of the same transparency and adamantine lustre as those of the carbonate, so that from appearance the two may be often confounded. With acids, however, the sulphate of lead affords no marked reaction, and this forms one distinguishing feature of the two compounds.

Before the blow-pipe the sulphate decrepitates, and then melts; in the oxidising flame it fuses into a transparent globule, which on hardening turns milk-white: in the inner flame it effervesces, owing to the evolution of sulphurous acid, and is quickly reduced to the metallic state. Samples of this mineral afforded to KLAPROTH the annexed composition.

	Anglesea.	Wanlockhead.
Protoxide of lead,..........	71·0	70·50
Sulphuric acid,.............	24·8	25·75
Water,.....................	2·0	2·25
Loss,......................	2·2	1·50
	100·0	100·00

Its density has been determined by STROMEYER, and found to be between 6·23 and 6·3, and its chemical symbol in the pure state, is $PbO\ SO_3$.

Phosphate of lead is a mineral of rare occurrence, although it is met with in many of the lead mines of Cornwall, and at the Lead Hills and Wanlockhead in Scotland. It crystallizes in hexagonal prisms, which are sometimes transparent, though more generally of a bright green, or brown, and sometimes of a fine orange color, derived from the presence of a small quantity of chromate of lead. Before the blowpipe, on charcoal, it melts in the outer flame into a globule which crystallizes on cooling, and becomes brown; in the reducing flame, the lead appears bluish, is luminous while hot, and on cooling crystallizes with large facets of a lighter color. Its specific gravity is from 6·5 to 7·0, and its centesimal composition, according to the analyses of KARSTEN and WÖHLER, as follows:—

	From Bohemia.		From Cornwall.
Phosphate of lead, ...	89·268	....	89·110
Chloride of lead,............	9·918	....	10·074
Phosphate of lime,..........	0·771	....	0·682
Fluoride of calcium,.........	0·137	....	0·130
	100·094		99·996

	From Zschopau Wohler.
Oxide of lead,..........................	82·29
Phosphoric acid,.	15·73
Chlorine,.........	1·98
	100·00

Chromate of lead is a very beautiful mineral, of a deep or hyacinth red color, and crystallized in oblique rhombic prisms, the cleavages of which show it to be translucent on the edges; it possesses an adamantine lustre, and gives an orange-yellow streak. It is, however, very rare, being found only in the Brazils, and at Beresof in Siberia. An artificially-prepared chromate of lead, forms the *chrome-yellow* of painters. Specific gravity of the native mineral is about 6, and its composition corresponds with the formula $Pb\,O, Cr\,O_3$.

Sulphide of lead—Galena; Bleiglanz, German; *Plomb Sulfuré,* French.—This is the most diffuse, and at the same time the most abundant ore of lead known; it forms veins and beds both in the primary and secondary rocks. At Freyberg in Saxony, it is found in veins in gneiss; at Sala in Sweden, it is met with in the primitive limestone; and at Clausthal and Newdorf in the Hartz, Przibram in Bohemia, and several other districts, clay-slate forms the repository of the metallic veins. The grauwacke of Dumfries-shire and the killas of Cornwall are traversed by lodes in which the mineral is contained; whilst in Derbyshire, Cumberland, and the other northern districts of England, and also several other localities on the Continent, it is extracted from amidst the mountain limestone. Valuable deposits of galena are worked at many other places besides those mentioned above. Wales and Ireland afford large quantities of the mineral. In several of the French departments it is found in considerable abundance, especially at Huelgöet and Poullaouen in Brittany, at Pontgil and Puy-de-Dome, and Villefort in the department of Lozère. Catalonia, Grenada, and the granite hills of Linares in Spain afford sulphide of lead. Extensive deposits of galena occur in the United States, particularly in Missouri, Illinois, Iowa, and Wisconsin.

Galena frequently appears under different forms, and is variable in its composition. Usually, it has a metallic lustre, and a leaden-grey or blackish-grey color. The primary form of its crystal is the cube; but it occurs in the form of octahedra and its varieties. Its structure is lamellar, and its cleavage, which is highly perfect, parallel to the planes of the cube. The specific gravity of the mineral is 7·5 to 7·7, and, when pure, it is composed of lead and sulphur, in the ratio of 86·55 of lead, and 13·45 of sulphur. The amount of lead, however, is subject to variation, owing to the presence of more or less silver, which is invariably associated with it, and also that of other metals, such as antimony, zinc, iron, copper, and arsenic. The following analyses of samples of galena show its usual composition:—

	Brudant.		Westrumb.		Thomson.
Lead,...............	79·6	....	83·00	....	85·13
Sulphur,.............	13·4	....	16·41	....	13·02
Silver,..............	7·0	....	traces	....	—
Loss,................	—	....	0·59	....	1·85
	100·0		100·00		100·00

It may be remarked here that the presence of silver, notwithstanding the proportion may be so large as the one-fifth of the whole, does not materially alter the external characters of the galena; but when silver is present in that amount, other metals, such as antimony and bismuth, are also contained in the mineral in appreciable quantities. The richest silver-lead ore is that found at Tarnowitz in Silesia, which contains about a fifth of its whole weight of silver; the usual proportion of this metal is, however, from 0.0001 to 0·003 per cent., and the ore is designated by the Germans *Weisgültigerz.*

The principal varieties of this mineral are *specular galena* and *blue lead.* The former is found in some of the Derbyshire mines, where it forms very thin coatings on the walls of the veins, so as to give the latter the appearance of looking-glasses. On this account it is designated *slickenside;* it explodes with a loud report when accidentally scratched in the mine. *Blue lead* is a kind of galena which is of frequent occurrence, having a hue between leaden-grey and indigo-blue. Other compound sulphides of lead with sulphides of silver, antimony, and bismuth are known; but these will be referred to afterwards.

Galena is a protosulphide, and is therefore represented by the symbol $Pb\,S$.

PREPARATION OF PURE LEAD.—As prepared from the ores of lead by the metallurgical processes in ordinary use, and which will be described presently, the lead of commerce is impregnated with other metals in small quantity, such as silver and tin, and occasionally traces of arsenic, antimony, copper, iron, and zinc, when the ores operated upon contain these metals. To obtain chemically pure lead, it is necessary to work upon the ordinary product with such reagents as will cause the separation of these metals. The method recommended is to heat the nitrate of oxide of lead in a crucible, and to reduce the litharge so produced with charcoal in a covered crucible, or with hydrogen gas at a red heat, presupposing that the lead salt is quite pure; but should it contain nitrates of other metals, such as silver and the like, these will pass into the reduced lead. This fact has been repeatedly proved, and even when great care has been bestowed upon the preparation of the lead salts with a view to their reduction, traces of silver have been detected in the resulting metal.

When lead absolutely free from silver is required, it is necessary to dissolve the lead of commerce in nitric acid, and to crystallize the nitrate thus formed by concentrating the clear solution; then precipitate the metallic base from the fluid with sulphuric acid; wash well the insoluble sulphate of lead, and finally reduce the latter by fluxing it with pure carbonate of soda and ground resin in a lined Hessian crucible. The button of metal which is thus obtained may be relied upon as being *absolutely pure.* The nitric acid has the effect of precipitating any tin and antimony as oxides; and during the subsequent crystallization of the lead salt from the clear filtered liquid, much of the silver will be left in the mother liquor, and the last traces of this metal are got rid of by precipitating the lead as a sulphate, and washing thoroughly. A very pure lead, so far as freedom from silver is concerned, is obtained by reducing the litharge which results from the furnaces of cupellation, as those at Freiberg in Saxony, and this is well adapted for the assayer's use. It may also be prepared by electrical agency, as by introducing a bar of zinc or iron into a solution of nitrate or acetate of lead carefully prepared; but by this means absolute purity is not insured, as the easily reducible silver, if contained in the salt operated upon, will likewise be precipitated.

CHEMICAL PROPERTIES OF LEAD.—The affinity of lead for oxygen is very great, even at ordinary temperatures; but this is increased when its temperature is elevated. Under the latter condition, it burns in the air with a bluish-white light, and affords oxide of lead or litharge. FARADAY has shown, that when finely divided, this metal is more inflammable than gunpowder. Nitric acid acts energetically upon lead, converting it into an oxysalt of this acid; acetic acid likewise dissolves it, but sulphuric and hydrochloric acids have only a feeble action upon it, especially in the cold. With the aid of heat, however, concentrated sulphuric acid dissolves it with the evolution of hydrogen.

At a red heat, hydrochloric acid vapor acts upon lead, producing a chloride of the metal and liberating hydrogen. This metal is capable of uniting with all the non-metallic elements, with the exception of hydrogen, borium, silicium, and carbon; with all the metals, except iron, it enters readily into combination, giving alloys which are of considerable importance in the arts, and some of which have been described under the heads, ANTIMONY, BISMUTH, *et cetera.* Its oxides, which are numerous, are employed for various useful purposes, and one of them, the protoxide, commonly known as litharge, readily combines with all the oxygen acids, forming salts, some of which are used in the arts to a very large extent. In the form of sheet lead and lead piping, this metal is applied to a great variety of purposes. To the metallurgist it offers a ready and advantageous means of obtaining silver and gold in their purity, by alloying them with it, and subsequently removing the lead from the compound metal by cupellation.

PRINCIPAL LEAD MINES.—Before entering upon the details of the processes involved in the production of metallic lead from the ores, it may not be uninteresting to lay before the reader the chief mines producing galena, and some of the circumstances connected with them, as stated by URE.—The principal mines at present worked in the world are the following:—

1. Poullaouen and Huelgöet, near Cairhaix in France, department of Finisterre, being veins of galena, which traverse a clay-slate resting upon granite. They have been in operation for upwards of three centuries; the workings penetrate to a depth of three hundred yards, and in 1816 furnished five hundred tons of lead per annum, out of which one thousand and thirty-four avoirdupois pounds of silver were extracted.

2. At Villefort and Viallaz, department of the Lozere, are mines of this ore, said to produce one hundred tons of lead, with eight hundred and eighty avoirdupois pounds of silver.

3. At Pezey and Macot, to the East of Moutiers in Savoy, a galena mine exists in talc-schist, which produces annually two hundred tons of lead, and about twelve hundred and thirty pounds avoirdupois of silver.

4. The mine of Vedrin, near Namur, in the Low Countries is opened upon a vein of galena traversing compact limestone of a transition district.

5. In Saxony the galena mines are so rich in silver as to cause the lead to be regarded as a secondary product, or entirely overlooked.

6. The lead mines of the Hartz have been likewise considered as silver ores.

7. Those of Bleiberg, on the Eifel, are of the same description.

8. The galena mines of Bleiberg and Vallech in Corinthia, in compact limestone.

9. In Bohemia to the South-west of Prague.

10. The mines of Joachimsthal and Bleistadt, on the Southern slope of the Erzgebirge, produce argentiferous galena.

11. There are numerous lead mines in Spain, the most important of which are those in the granite hills of Linarès, upon the Southern slope of the Sierra Morena, and in the district of the small town of Canjagar. Enormous masses of galena are extracted sometimes from the mines of Linarès. There are mines of sulphide of lead in Catalonia, Grenada, Murcia, and Almeria, but the ore of the last locality is worked for the silver it contains.

12. The lead mines of Sweden are very argentiferous, and, like the last mentioned, are worked to extract the silver.

13. In the district of Daouria the lead mines are numerous and rich, lying in a transition limestone which rests on primitive rocks; their lead is neglected on account of the silver.

14. Great Britain is, of all countries in the world, that which annually produces the largest quantity of lead. According to M. VILLEFOSSE, in his *Richesse Minerale* published in 1819, this kingdom had furnished twelve thousand five hundred tons of lead, being more than the rest of Europe produced; it appears, however, from more recent documents, that the above estimate is too low. Mr. TAYLOR in 1822 rated the total produce of the United Kingdom per annum at thirty-one thousand nine hundred tons, a quantity fully two and a half times greater than that stated by VILLEFOSSE. TAYLOR distributed this product among the different districts as follows:—

	Tons.
Wales—Flintshiro and Denbighshire, ...	7,500
Scotland—in transition-grauwacke, ...	2,800
Durham, Cumberland and Yorkshire—in carboniferous limo	19,000
Derbyshire— probably in carboniferous lime,.....	1,000
Shropshire,..................................	800
Devon and Cornwall—transition and primitive rocks, ...	800
Total, ...	31,900

Hence it may be seen, that the adjacent parts of the counties of Durham and York furnish of themselves nearly three-fifths of the total product.

In 1835 the entire quantity was estimated by TAYLOR at 46,112 tons, of which 19,626 tons were furnished by Northumberland, Durham and Cumberland; the mines of Mr. BEAUMONT of themselves yielding ten thousand tons. The annexed table shows the increase in 1847:

	Lead Ore. Tons.		Lead Tons.
England, ...	59,614¼	....	39,507½
Wales, ...	18,147¾	....	12,294
Ireland,...............	2,251	....	1,380
Scotland,..............	1,159	....	822½
Isle of Man,...........	2,575	....	1,699
	83,747		55,703

15. In the United States, the most remarkable lead region—and, according to BOOTH, probably the largest in the known world—where the galena is disseminated in beds of greater or less extent, is in Wisconsin, Iowa, Illinois, Missouri, and Kentucky.

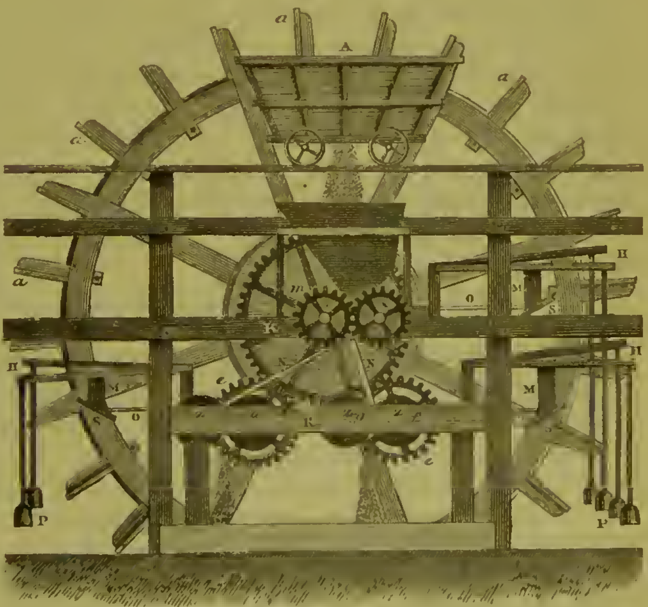
The former three may be regarded as a distinct region of ninety miles from East to West, and sixty miles from North to South. Another district is in Missouri, to the South of the river so named, about eighty miles North and South, and fifty miles East and West. The lower part of Illinois, and part of Kentucky, appears to be a third district. In the first the lead found is very pure, and it is remarkable besides for the enormous crystals of galena which it produces; the second district gives often a less pure lead, which is largely associated with very pure barytic minerals; and in the third, much of the galena contains sulphide of antimony. Athough extensively explored, this immense metallic region of the Mississippi valley remains to be fully developed. The best argentiferous vein yet opened in the United States, is probably that in Davidson County, North Carolina.

PRELIMINARY OPERATIONS.—Rarely is galena found of such purity as to be at once in a fit state for the action of the fire; it is generally compounded with the stony substances of the strata in which the deposit exists, and also with other minerals of a different nature. The crude product raised from the mine is, therefore, submitted to various processes of dressing, to bring it to an average standard richness. In England these preliminary operations are divided into three classes, namely, *the sorting and cleansing of the ore, the grinding, and the washing.*

Sorting and Cleansing the Ore.—At several of the British mines this operation is performed at the mouth of the mine, by the aid of sieves constructed of iron wire, the strands running parallel at an inch distance, thus forming openings one inch square. The material is thus separated into two batches, and, by using finer gauzes, into more varieties. Sometimes the clay, or mud, is removed from the ore by placing it on a sieve with small meshes and agitating the whole in water. In many parts of Derbyshire, however, the ore is merely stirred about with a shovel in a trough filled with water; but this method, which is termed the *standing buddle* system, is obviously very imperfect. Another apparatus, called the *running buddle*, serves at once to sort and cleanse the ore. It is similar to the inclined plane used for copper ore. This contrivance, which was formerly the only one in general use at Alston Moor, has been supplanted by another called the *grate*. This is a grid constructed of iron bars one inch thick, and twenty-four to thirty inches long; these are fixed parallel to one another, and horizontally, at a distance of one inch apart. A wooden canal above the grate, conducts a stream of water over its middle, and an inclined plane set beneath it, and leading to a hemispherical basin, serves to recover the metallic powder which is detached from the mass.

Grinding.—After assorting the ore it is crushed to fine powder. Formerly the *bucker* was in frequent request, but is now giving place to the crushing machine, which effects a considerable saving in time and labor, and is, therefore, coming very rapidly into general use. This machine is represented in the annexed drawing —Fig. 319—the description of which is taken from the latest edition of URE'S excellent Dictionary. It is composed of one pair of fluted cylinders, X X, and of two pair of smooth cylinders, Z Z, Z′ Z′, which are immediately used for crushing the ore. The two cylinders of each of the three pair turn simultaneously in an inverse direction, by means of two toothed wheels upon the shaft of every cylinder, which work by pairs in one another. Motion is communicated by a water-wheel, the circumference of which is represented by *a a a*. One of the fluted cylinders is placed on the prolongation of the shaft of this wheel, and which carries besides, a cast-iron toothed wheel, gearing into two others, *e e*, fixed upon the ends of the two smooth

Fig. 319.



cylinders. Above the fluted cylinders is placed a hopper from which the ore with which it is charged from the waggon, A, and which advance upon tramways, till they come directly over the hopper; their contents are emptied through a trap-hole in their bottom. Below the hopper there is a small bucket called a shoe, in which the ore is shaken down, and which throws it without ceasing upon the cylinders, in consequence of the constant jolts given to it by a crank-rod attached to it and moved by the teeth of the wheel, *m*. The shoe is so regulated, that too much ore can never fall upon the cylinders so as to obstruct their movements. A small stream of water which is conducted into the shoe, spreads over the cylinders and prevents them from getting overheated. After the ore has passed between the fluted rollers, it falls upon the inclined planes, N N, which turn it over to one or other of the pair of smooth rollers.

These are the essential parts of this machine; they are made of iron, and the smooth ones are case-hardened, or *chilled*, by being cast in iron moulds. The gudgeons of both kinds move upon brass bushes, fixed upon iron supports, K, made fast by bolts to the strong wood-work basis of the whole machine. Each of the horizontal bars has an oblong slot, at one of whose ends is solidly fixed one of the plummer-blocks or bearers of one of the cylinders, *f*, and in the rest of the slot the plummer-block of the other cylinder, *g*, slides—a construction which permits the two cylinders to come into contact, or to recede to such a distance as circumstances may require. The movable cylinder is approximated to the fixed one by means of the iron levers, H H, which carry at their ends the weights, P, and rest upon wedges, M, which may be slidden on the inclined plane, S. These wedges then press the iron bar, O, and make it approach the movable cylinder, by moving the plummer-block that supports its axis. With such an arrangement, should very large or hard pieces of ore fall between the cylinders, one of the rollers would recede, and let the piece pass without doing any injury to the mechanism.

Besides the three pair of cylinders which constitute essentially each crushing machine, there is sometimes a fourth which serves to crush the ore when not in large fragments; for example—the moderately rich pieces, called cuttings, and the poorer kinds or chats produced by the first sifting. The cylinders composing that accessory piece, which, on account of their ordinary use are called *chats-rollers*, are smooth and similar to Z Z Z′ Z′ in the foregoing figure. One of them is usually placed upon the prolongation of the shaft of the water-wheel, at the opposite side of the principal machine; and the other which is placed alongside, receives its motion from the first by means of toothed wheel-work. The ordinary stamping process is in some places combined with the use of the crushing rollers, especially if the gangue be too hard for the latter to grind.

Washing.—After the operation of grinding comes the process of washing, properly so called. This is effected in various ways, such as by the *jigger*, the *inclined-plane*, the *dolly-tub*, *et cetera*, all of which are so obvious in principle, and bear so much resemblance to similar apparatus already described in the articles Copper and Gold, as to render a detailed description unnecessary. It may be stated, however, that in general much waste is occasioned in the English establishments in cleansing the ore, and the washing is not carried to the same degree of perfection as in other countries; doubtless from the circumstances that fuel in this country is plentiful and cheap, and labor is dear, while in Brittany and other localities the reverse is the case. In Cumberland the washing of the ore is usually let by the piece, and the men are paid according to its richness; thus, two shillings and sixpence is paid for cleansing fifteen hundred-weight of one kind, and for others, a sum ranging up to ten shillings, according to the quality of the ore.

Theory of Lead Smelting.—The smelting of lead ores with a view to the metals which they contain, demands no little amount of attention, to perform the operation in the most effective manner. The details of the process differ considerably according to the position of the works in relation to fuel, the nature of the ore, and its peculiar richness in silver, *et cetera*. So far as regards the reduction of the metallic lead, the principles of the various reactions may, however, be referred in most cases to the decomposition which takes place at a high temperature, by the mutual effect of an oxidised compound of lead and the sulphate, whereby the non-metallic elements are driven off, generally as sulphurous acid, and the metal is left. To bring about such a change it is customary to submit a portion of the galena to a preliminary roasting in contact with air, during which considerable quantities of sulphate of lead are produced by the oxidation of the sulphur and metal of the galena. This being done, the roasted and the crude materials are apportioned and heated in a furnace with due precautions, till the lead flows off, leaving a residue of the crudities of the ore, together with a portion of the unreduced substance. Much of the tact and knowledge of the smelter is shown in the manner in which the admixture is made, and in the subsequent application of the heat. And without knowing the reactions which take place, the operator can never be certain of success, but is subject to the risks and hazards arising from the different qualities of ore and imperfect roasting.

Indeed, the knowledge of the behavior of the galena under the influence of a high temperature, is the key to a comprehensive view of the whole business of lead smelting. When sulphide of lead—galena—is heated in a close vessel, out of contact with air, no change takes place beyond fusion, if the heat be sufficiently intense. This is not the case, however, if air be admitted, and allowed to flow over the fused mass: for then not only will the sulphur be oxidised, but a portion of the metal will be volatilized. Hence it is, that in operating upon lead ore, in particular kinds of furnaces, large quantities of the lead are driven off in vapor.

When the temperature applied is low, and the air freely circulates through the ore, the sulphide is converted into sulphate of lead, which resists a higher temperature, and is consequently more fixed. A mixture of sulphate of lead and of sulphide, affords upon the application of heat sulphurous acid and metallic lead, which react upon one another, as represented in the formula:—

$$\underbrace{Pb\,O,\ SO_3}_{\text{Sulphate of lead.}} + \underbrace{Pb\,S}_{\text{Sulphide of lead.}}$$

Resolved into

$$\underbrace{2\ Pb}_{\text{Lead.}} + \underbrace{2\ SO_2}_{\text{Sulphurous acid.}}$$

or

$$Pb\,SO_4 + Pb\,S = 2\ Pb + 2\ SO_2$$

From this it may be seen, that by the action of the heat, one equivalent of the sulphate and one of the sulphide afford two equivalents of lead—that is, the whole of the metal which they contain—and two equivalents of sulphurous acid. By making the composition of the charge, from which the metal is to be eliquated, as near as possible to the above formula, there is no doubt but that the most perfect and economical decomposition will follow, and nothing will be left to desire beyond the regulation of the proper heat. It is not so, however, when the ratio between the sulphate and sulphide in the charge is altered, and more especially if the sulphate be in excess. Thus, if instead of an equal number of equivalents of the two ingredients, one of the sulphide and two of the sulphate be employed, the effects will be less advantageous; for in this case, only one equivalent of metal will be obtained, as the equation shows.—

$$\underbrace{2\ Pb\,O,\ SO_3}_{\text{Sulphate of lead.}} + \underbrace{Pb\,S}_{\text{Sulphide of lead.}} =$$

$$\underbrace{Pb}_{\text{Lead.}} + \underbrace{SO_2}_{\text{Sulphurous acid}} + \underbrace{2\ (Pb\,O,\ SO_2)}_{\text{Sulphite of lead.}}$$

A further increase of the amount of the oxidised compound would be productive of still less satisfactory results, and hence, if the ratio of the sulphate to the sulphide of lead be as three to one, no metal will be obtained, as shown by the formula:—

$$\underbrace{3\ (Pb\,O.\ SO_3)}_{\text{Sulphate of lead}} + \underbrace{Pb\,S}_{\text{Sulphide of lead.}} = \underbrace{4\ (Pb\,O,\ SO_2)}_{\text{Sulphite of lead.}}$$

but instead, four equivalents of oxide of lead—Pb O—and four of sulphurous acid result. From these facts the obvious inference is drawn, that an excess of the well-roasted ore, which represents the sulphate of lead, must be avoided when compounding the charge. By employing a larger quantity of the galena representing the sulphide of lead, than is stated in the first of these formulæ, the consequences are not so bad as those just explained; for in this case, a portion of the sulphur, usually amounting to one-half, passes off as sulphurous acid, and the remainder is left united with the metal as a subsulphide of lead, which requires a much less amount of roasted ore for its reduction than the ordinary galena; neither does it require such a high temperature: and, owing to its entering into rapid fusion, it forms a layer upon the reduced metal, whereby the latter is preserved from the oxidising influence of the air.

Sulphide of lead is decomposed, without the intervention of an oxide of this metal, in a very perfect manner by metallic iron, which takes up the sulphur from the lead, and forms therewith sulphide of iron:—

$$\underbrace{Pb\,S}_{\text{Sulphide of lead}} + \underbrace{Fe}_{\text{Iron.}} = \underbrace{Pb}_{\text{Lead.}} + \underbrace{Fe\,S.}_{\text{Sulphide of iron.}}$$

The heat required to effect this change is, however, much more elevated than that which answers for the preceding decompositions. An oxide of iron, such as results in one of the processes to which pyrites are subjected in the manufacture of sulphuric acid, would answer the purpose of the iron much better; for a lesser quantity of the material would suffice to reduce a large weight of the galena, and at a comparatively low degree of heat. In this case the change which would result is symbolized in the annexed equation:—

$$\underbrace{7\ Pb\,S}_{\text{Sulphide of lead}} + \underbrace{2\ Fe_2\,O_3}_{\text{Sesquioxide of iron.}} = \underbrace{7\ Pb}_{\text{Lead.}} +$$

$$\underbrace{4\ Fe\,S}_{\text{Sulphide of iron.}} + \underbrace{3\ SO_2}_{\text{Sulphurous acid}}$$

A double advantage may be derived from the adoption of this method of decomposing the galena, namely, the reproduction of iron pyrites, which may be utilized in the manufacture of sulphuric acid.

Of all these reactions the simplest in execution is that wherein metallic iron is employed, for only a mere heating is necessary to produce the lead. In large works, however, this is never resorted to, unless the mineral possesses such properties as necessitate the application of iron. That which is most general is the first-mentioned, in which a sulphate of the metal is produced, and this, mixed with galena, is subsequently acted upon by the heat to separate the metal. By a preliminary roasting the galena is converted into sulphate of lead, either in an open heap or in a roasting furnace. The method of heating the subsulphide of lead is frequently resorted to with advantage, as by it large quantities of metal are obtained, together with protosulphide of the metal which remains, and may be further operated upon.

THE FURNACE.—Three kinds of furnaces are used by lead smelters. In England and Wales the reverberatory form is exclusively employed, and no other affords more rapid results; the *Scotch Furnace* has been adopted at Alston Moors, and in some places on the Continent; and the high or tuyere furnace is employed where the ore is refractory or fuel is scarce.

The reverberatory furnace, called the cupola, is of very ancient origin, and has long been in vogue in North Wales, whence the models were brought to Derbyshire about the year 1747 by a company of Quakers. Long before this, the lead ore of Derbyshire and the North of England was smelted in very rude furnaces, called *boles*, the fire being urged by the natural force of the wind. For this reason the furnaces were always constructed on the Western side of an eminence. To these succeeded furnaces urged by bellows, similar to those of a smith's forge, and worked by water-power.

The form of the reverberatory is represented in plan, Fig. 320, and in elevated section, Fig. 321. Generally, the sole of the furnace, A, is eight feet in length by six in breadth, and is constructed of the fused slags

Fig. 320.

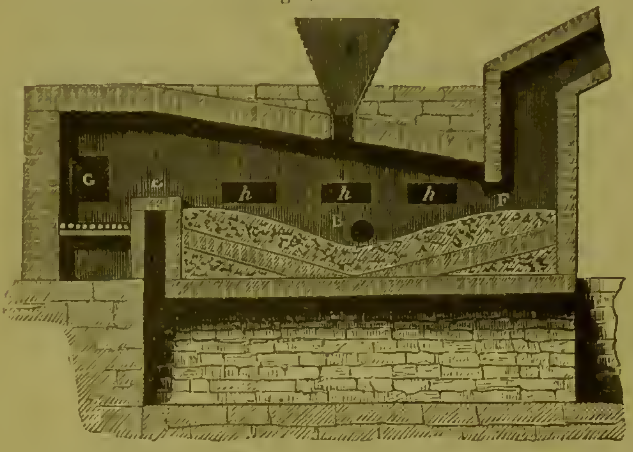
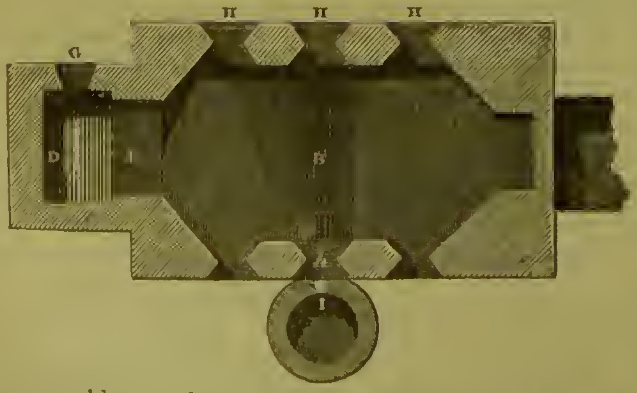
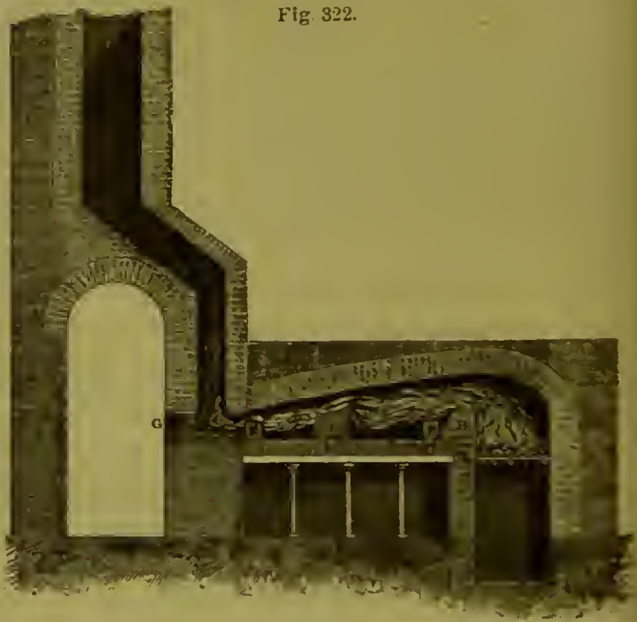


Fig. 321



from the preceding operations, worked into the necessary form, during the time they are in a semi-fluid state, by a strong iron rake. The shape of the sole is that of a shallow basin, in which the fluid metal collects at the deepest part, and is drawn off by a tap-hole shown in the section at B. By means of a solid bridge, E, of firebrick, the fire, D, is separated from the hearth; it is usually about two feet thick, and about one foot in height, leaving from fourteen to eighteen inches space between it and the arch for the flame to pass over. As shown in the drawing, the arch, C, gradually declines towards the further extremity of the hearth, from which it is elevated only six inches, the height from the deepest part of the depression in the bed being only two feet. At the extremity of the furnace, opposite the fire, there are sometimes two openings, separated by a triangular prism of firestone, which lead to a flue, F, a foot and a half wide and ten feet long, which is recurved towards the top, and runs into an upright chimney fifty-five feet high. This flue, for a short distance from the furnace, is covered with flat tiles closely jointed in fireclay, but which may nevertheless be easily removed. Such an arrangement is necessary in order that the *lead fumes*, which at a high temperature are freely sublimed, may be cleared away and the freedom of the draught insured. One of the sides of this furnace is called the *laborer's side*, being that from which the fire is supplied with fuel through the door, G; on the same side are three other openings, H H H, which are closed by sliding plates, and vary in area from six inches square to about eight inches by twelve. When necessary, the charge is stirred through these openings, and they are also useful for admitting air when the process of roasting requires it. Opposite is the *working side*, in which are five apertures; three corresponding with those on the other side, and similarly secured, and the other two, below them, used for running off the metal and scoria. Towards these last the bed of the furnace inclines in such a way, that the part which is opposite is nearly up to the aperture H, whilst at the tap-hole it is eighteen inches below H, on the same level. The lead flows into a cast-iron pan, I, set in a niche a little under the side. There is in the middle of the arch an opening, to which is fitted an iron hopper, where a charge of ore is deposited whilst that in the furnace is being worked; and when the latter is drawn off, the material in the hopper is let into the furnace, by drawing a slide.

Fig. 322.

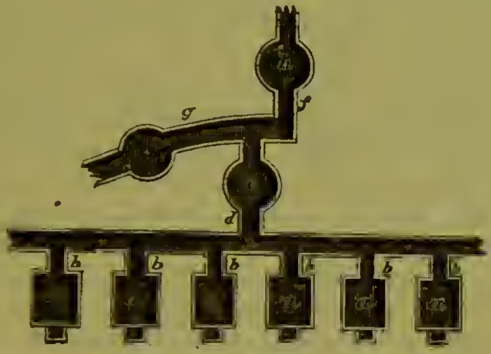


The preceding is the kind of furnace employed at Grassington in Yorkshire, and in which the roasting and smelting are conducted. In those localities where the two operations are conducted separately, as at Redruth and other places in Cornwall, the roasting furnace employed is that represented in Fig 322. A is the fire, and B the fire-bridge; C C, separate ducts by which the smoke passes off to the chimney; E E, working doors, which allow the workmen to spread and stir up the charge of ore as required; and F F, smaller apertures serving the same end, and admitting air for the combustion of the sulphur of the mineral. The sole of the furnace is a cast-iron plate, upon which layers of firebrick are accurately fixed together, the whole being supported upon pillars, as shown in the drawing. Besides the apertures already mentioned, there are others, G, generally at the end opposite to the fire, through which it is rabbled at intervals. The size of this furnace is smaller than that in which both the roasting and smelting of the ore are performed.

At the works near Holywell, North Wales, the furnaces employed are of that kind in which the roasting and smelting are performed successively; they are very similar in form to that already described, only that there is no opening for running off the slags. The hearth is hollowed out below the middle door of the furnace, the back and ends being made to slope towards this part. Twenty-four inches is the ordinary depth from the bottom of this basin to the sill of the door; but it varies a little according to the kind of ore operated upon. In the other details of the hearth and arch these furnaces are similar to those already mentioned. In this locality, however, the flues from all the furnaces enter one main, which leads to a chimney disposed as represented in Fig. 323.

Here the furnaces are shown as at *a a a*, and the separate flues, *b b*, opening into a main channel, *c c*, five feet deep by two and a half wide. Another one, *d*, six feet deep by three in width, opens from the latter into a circular chamber, *e*, fifteen feet in diameter, wherein, as well as in the conduits leading to it, the *lead-ashes* volatilized from the furnaces are intercepted. From *e* the smoke is conducted by a similar flue, *f*, which enlarges as it approaches the chimney, and where it is joined by the flue, *g*, from another department of the furnaces, to a depth of seven feet and a breadth of five. The chimney has a diameter of thirty feet at the base, tapering to the top, where it measures twelve, including the thickness of the walls; its height is one hundred feet; but as it stands upon an adjoining hill, which is about sixty feet above the level of the furnaces, the total height of the flue may be said to be about one hundred and sixty feet. Such an arrangement is necessary, in order to draw off, out of the range of the inhabitants, animals, and vegetation of the neighborhood, the enormous quantity of sulphurous acid which is evolved from the thousands of tons of ore worked annually.

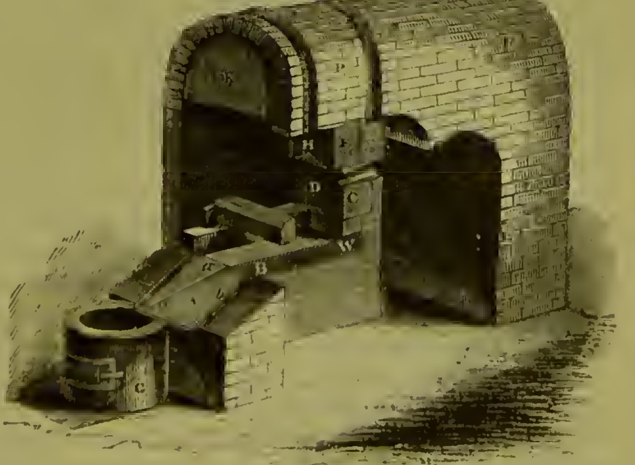
Fig. 323



In many parts of England, more especially in the counties of Durham, Cumberland, and Northumberland, the smelting of the lead ores is conducted in the *Scotch furnace*, or *ore hearth*. It is shown in Fig. 324, and consists of a rectangular cavity of masonry, *a* B W, twenty-four inches in length by a breadth of twelve, and a depth varying from twenty-two to twenty-four inches, the whole inclosed in an arched hood, P. A considerable portion of the hood, on the near side, is removed to show the interior arrangements. The cavity is entirely lined with cast-iron, the bottom portion, B W, being one entire piece, having a ledge five inches in height and two in thickness surrounding every part of it, except on the side facing the *workstone*, A, placed at one end of the rectangular construction. The ledge upon the side, B W, is removed to show the interior of the cavity. The workstone, A, is likewise surrounded by a ledge, *b*, on all sides except that near the hearth, and which either rests on the ledge surrounding the hearth bottom, or is united to it and forms part of the casting. In either case it is fixed at an incline of about six inches. On the back edge of the furnace bottom is placed a prism of cast-iron, C D, called a *backstone*, six and a half inches square in section, and twenty-eight in length, on which rests the nozzle of the tuyere. Above this is placed another cast-iron prism of the same length, and eight inches in height, which is known as the *pipestone;* it has a cavity in its centre for the introduction of the tuyere, and projects about two inches over the hearth. A third *stone*, E H, is fitted on the latter, and completes this side of the furnace, making its total height from the sole-plate twenty-five and a half inches. Two prismatic castings, called *bearers*, are placed along the lateral sides, twenty-six inches long and five square, and projecting slightly over the edge of the workstone as well as of the posterior backstone; these contribute effectually to give solidity and fixity to the parts. These bearers support, through the intervention of several ranges of firebricks, a piece of cast-iron of the same dimensions as the lowest backstone, and which is called the *forestone.* This piece is in contact at each of its extremities with another mass of cast-iron, six inches cube, and supported on the brickwork; this is called the *keystone.* Finally, the spaces left between these keystones, at either side, are filled up with other blocks of castings similar to the latter.

When the workstone, A, is not connected with the sole-plate, B W, the space between them is filled up with a cement formed from ground bone-ash and galena, thoroughly mixed and pressed firmly into it. Before the workstone, and set in masonry inclosed in a cast-iron jacket, is the lead-pot, G, into which the freed metal flows through the channel, *a a*, which is sunk beneath the surface of the plate. It is placed close to the furnace, in order to prevent the escape of lead fumes as much as possible. This is more completely effected by the hood, P, in which is a flue communicating with a chimney, and in which is left a small door for the introduction of the ore and fuel. The movable iron plate, K, in front admits of being raised or depressed at pleasure, whenever the draught requires

Fig. 324.



it; and the blast, which is forced through the tuyere, is regulated by a valve placed in a pipe, which is approached by the door-way, L, left open for this purpose. Heavy iron bands are employed for binding the brickwork more firmly, as shown in the figure.

Smelting in Reverberatory Furnaces.—It is seldom that any other kind of furnace is adopted for lead smelting in England, besides those above-mentioned. The routine of working which the English smelter pursues when the reverberatory furnace is employed, will now be described.

The fact has been already stated, that the process of smelting is modified according to the nature of the ore. Generally speaking, the average richness of the English ores of lead is about seventy-five per cent. of metal; but in many specimens there is found not more than twenty per cent.; and, in fact, ore is often met with varying between these extremes. The remaining constituents are composed of sulphur, the stony matter of the rock in which the *lode* is found, *et cetera*, and which consists, for the most, of sulphate of baryta, carbonate of lime, silicates, and sometimes—as in some of the ores at Holywell—carbonate of zinc, and the like. In order to produce a fusible compound, which will melt at as low a temperature as possible, a judicious admixture of two, three, or more kinds of ore is made, according to the nature of the non-metallic impurities; and it is often found necessary to have recourse to fluxes. When, however, the gangue is of such a nature as to melt readily, such additions are unnecessary. A properly-conducted analysis of the ore will always enable the experienced manager to judge of the additions that are best calculated to favor the separation of the impurities.

In the lead works in the neighborhood of Alston Moor, as well as in those of Derbyshire, the charge is composed sometimes of as many as seven varieties of ore, and weighs only sixteen hundreds of one hundred and twenty pounds each; but in the very extensive works belonging to Messrs. Walker, Parker, and Company, the charge is twenty-one hundreds, and is rarely composed of more than two or three kinds of ore. In the latter works this weight of ore is put into the hopper; and, as soon as the furnace is brought to a dull red-heat, or after drawing out the slags from the last charge—if the furnace has been working already—the slide in the neck of the truncated cone is withdrawn, and the ore is allowed to precipitate itself upon the bed of the furnace, where it is spread out into an even layer, through the furnace doors at the back. No effort is made at this period to urge the heat; it is rather allowed to sink; and only a few spadefuls of coals are thrown upon the grate at intervals, to maintain the heat at the moderate standard required. After spreading out the ore, all the working doors, as well as the outlets for running off the slags and metal, are closed, and the damper is lowered. As soon as the ore becomes heated, and the sulphur begins to escape as sulphurous acid, if any rich slags remain from a preceding operation, they may be thrown into the furnace at the opposite doors furthest from the fire, and spread out like the ore. Air enters the furnace through a rectangular slit over the tap-hole; this is left open all the time that the roasting continues. After the charge of ore attains a dull red heat, and the sulphur begins to burn off, the heat produced is nearly sufficient to carry on the roasting, independently of the fire in the grate; still, this is maintained, but only feebly. At the expiration of a quarter of an hour, the ore is well turned over with the paddles, so as to present a fresh surface, and to cause the evolution of a fresh quantity of the sulphur. One hour and three quarters are devoted to this part of the operation, the intervals between the rabbling of the charge being occupied in casting the lead from a previous charge into pigs. In the course of the roasting of the ore, some metal is produced from the reaction of the rich slags thrown in at the upper door upon a portion of the galena; this metal is drawn off at the proper time. Coal is added generally to effect the reduction, and rabbled with the molten mass some short time previous to the metal being drawn off. Whilst the smelter is tapping off the reduced lead, and throwing the scoria—which floats upon the bath—back upon the furnace, the assistants are stirring up the ore with their paddles. The slags from the bath of metal, as well as the rich ones from the previous charge, being thus partly smelted, and the ore roasted or oxidised to a certain extent, all the doors of the furnace are opened, and the ore is thoroughly turned over towards that side on which they work.

At this period the vapors of sulphurous acid have considerably diminished, and the temperature of the interior of the furnace becomes lower. The lead, which before this rabbling and cooling was beginning to ooze out, is checked. Some coal is now thrown upon the fire; the damper is slightly raised to increase the draught—the doors of the furnace being all closed during the time that the firing is taking effect. This is recognized as the *second stage*, or *firing*: the first being the *roasting* of the ore. In about half an hour the furnace assumes a red heat, and the material contained in it begins to flow down the incline of the sole towards the basin. The doors at this juncture are opened, and the smelting matters pushed by the smelter to the front of the sole, near the bridge, where they are spread out by his assistant from the opposite side. A little quicklime is now thrown upon the bath of metal through the middle door, and the ore and melting matter is worked through the doors at the back for a quarter of an hour; then spread out upon the sole. Meanwhile the smelter, with a long rake or paddle, forces the slags from the surface of the metallic bath towards the bridge.

A little respite is now given to the operation, the doors being left open for a short period; during which the lead remains in repose, and the metal, which was forced back with the slag, descends again into the basin. It is assumed that the cooling of the furnace at intervals, in this manner, not only facilitates the separation of the gangue from the metal, but shortens the time of smelting in every way. Some fuel is thrown upon the grate, to maintain a moderate heat; and the workmen resume their rakes, and turn over the slags and ore. When this is done the doors are closed, and the grate is charged with the third firing; the damper is entirely drawn, and the furnace is left to itself for three quarters of an hour. This *third* firing is given three hours to three and a half after the charging; and at the end of the fourth hour the doors are again thrown open, and the charge stirred by the assistant opposite to the smelter's side, for the purpose of facilitating the flow of the metal into the basin of the hearth. The slags are once more pushed from the surface of the bath of metal by the smelter, and spread with the ore by the assistant. If the galena should happen to be silicious, a portion of the oxide of lead is taken up by the silica during the preceding period, and flows down upon the reduced matter in a matt. To decompose this a quantity of quicklime is thrown in from the front, agitated with the mass slightly; then the doors are once more secured, and the fire is replenished.

At this period the practice is to throw a little slack into the furnace, with the view of assisting in the reduction of the oxidised compounds of lead which may still exist, as well as to prevent the oxidation of the metal. This is the period of the *fourth* firing, and lasts forty minutes; so that its effect takes place in about four hours forty minutes from the hour of charging. Now the doors are opened, the smelter pierces the tap-hole, and allows the reduced metal to flow out into the basin sunk in the floor outside. Quicklime is thrown upon the slags which remain, in order to dry them; he then pushes them towards the back, whence the assistant draws them out at the back doors.

Thus the smelting of a charge of ore of twenty hundred, at the Dee Bank Works, usually occupies a period of four hours and a half; but when the slags, instead of being dried up, are melted, a further firing is necessary, and the operation occupies a longer time. Generally speaking, the furnace is ready for the reception of another charge in six hours; so that, in the twenty-four hours, there are four charges worked off by every furnace. The week's work extends to twenty-two charges, generally, although the standard is limited to sixteen. Unless the ores are very refractory, the quantity of lime required for each charge amounts to one hundredweight; but some ores are worked which take as much as two hundredweight of this agent. The lead from the charge of twenty hundredweight of ore averages from fifteen to sixteen hundredweight. The richer slags which form on the bath of metal are worked with the succeeding charge, in the manner described; but the remainder are smelted—by a process to be described further on—in *slag-hearths*, built on the German principle. It is often found necessary, when very fusible slags are produced in the furnace, or the metal becomes more or less oxidised, to employ billets of wood, in the same way as the *polling* is effected in the refining of copper; only that, in the case of lead, it is not performed within the furnace, but in the pan without, whilst the lead is hot. The quantity of coal employed for the smelting of each charge weighs, on an average, about half a ton.

In the Grassington works, Yorkshire, the ore is composed of galena, mixed with carbonate of lead, and a gangue of carbonate of lime and sulphate of baryta. Here, as at Holywell, the charge is generally twenty hundreds. The period of roasting extends from three to three and a half hours, and the melting for metal succeeds almost in the manner described. Quicklime, mixed with slack, is used to dry the slags, which are spread upon the sole of the furnace; and the melting for metal, and drying of the slags, are repeated three times in succession. Fluoride of calcium—fluor spar—is sometimes used as a flux, and the bath of metal in the basin of the furnace is always kept covered with lime. Seven to eight hours are occupied by the working of the charge, and the metal obtained weighs from sixty-one to seventy-two per cent of the ore. Owing to the materials being less refractory, the consumption of coals here is somewhat less than at Holywell.

At Lea, in the neighborhood of Alston Moor, the ores smelted are, for the most part, of two kinds—namely, an almost pure galena, and another ore of lead, which has the annexed composition :—

	Centesimally.
Sulphide of lead, ...	55·00
Carbonate of lead,........	23·00
Sulphate of baryta,...	19·00
Clay, ...	3·00
	100·00

In the reverberatories at Pezay, in France, fir-wood is used for fuel, of which about four stères are required for smelting each charge of one thousand two hundred and fifty kilogrammes, or twenty-five hundredweight of the ore, the richness of which averages about seventy-six per cent. of metal.

In all the works mentioned, and in fact wherever the reverberatory furnace is employed, the principles of the operation are explained thus:—During the first stages, a greater or less quantity of sulphate of lead mixed with oxide is produced; the several rabblings which are given to the charge during the period that the temperature is retained at a low degree, tend to increase these substances, and to mix them more intimately with the ore, so that when the firing for the production of metal is given, the reaction,

$$\mathrm{Pb\,S + PbO\,SO_3 = Pb_2 + 2\,SO_2}$$

as formerly described, may take place. The partial cooling of the furnace after the second firing, is supposed to forward the same ends, inasmuch as the temperature which, if continued, would melt the materials and considerably retard oxidation, is slackened, and after the proper interval, the charge bears to be stirred as when in its most friable state.

Smelting in Blast Furnaces.—The use of the blast furnace involves the necessity of a somewhat different treatment. The *Scotch furnace* or *ore-hearth*, described at page 465, may be taken as the type of this kind of furnace when adapted to the smelting of lead ores.

Generally very rich ores are operated upon where the Scotch furnace is employed; and these are subjected before smelting to a preliminary roasting in a furnace of the reverberatory class.

From nine to eleven hundredweight of ore constitute a charge, and two and a half to three hours are required to effect their calcination; so that about nine charges are drawn during twenty-four hours. The heat of this furnace is kept purposely lower than the melting point of the galena, but sufficiently high to effect combustion of the sulphur with the oxygen, whereby it is converted partly into sulphurous and partly into sulphuric acid. Evidence of these changes is observed in the heavy dense fumes which fill the furnace and escape into the chimney. When a portion of the charge softens and becomes somewhat agglutinated, a fresh surface is presented to the flame by rabbling, and moving the hotter material to a colder part of the hearth. When slime ores are operated upon, the temperature is kept such as to render the mass somewhat pasty, in order to prevent the loss which the draught would occasion if the ore retained its friable quality. The roasting of the charge being effected, the material is drawn out by the door, and falls into a tank or well of water, whence it is subsequently raised and dried before submitting it to the operation of smelting. In this state it is a compound of oxide of lead, sulphate, and subsulphate, with undecomposed sulphide. Roasting the mineral in heaps was a practice once common enough, but is now obsolete, at least in England and the neighboring countries.

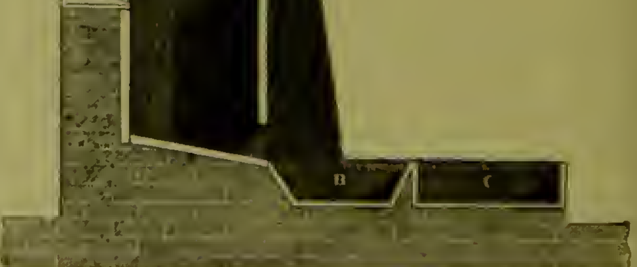
The roasted ore and coal are introduced into the smelting furnace after the latter has been heated by a preliminary firing, and the blast is thrown in either by a good condensing engine or by a fan worked by steam. To heat the furnace, the practice in the English smelting districts is to fill the cavity with peat, cut into the usual prismatic form, taking care that those towards the front are regularly placed in layers, one above another. A few ignited coals are placed immediately before the tuyere or nozzle, by which the blast enters, and the air is forced in gently, in order to ignite the mass. Some small coal is also thrown on the peat, when it is thought that the heat produced by the peat alone is insufficient to bring the furnace to the proper temperature. When the whole of the fuel is ignited, and the furnace has acquired sufficient heat, the *browse* from a preceding charge, if there be any, is thrown upon the ignited mass, and the blast continued as before. In a short time the portion of browse that remained on the hearth, together with that added, softens, and is drawn out upon the workstone by means of a large rake called a *goweloch*. Here the experienced workman is enabled to distinguish and separate the poor slag from the richer material by the color; the former, which has a shining grey appearance, is thrown with the spade in a heap to the right of the operator, and the latter is set aside to be again returned to the furnace. If the browse retains much slags, or, owing to its being very fusible, comes out in a pasty state, some quicklime is added, which, by uniting with the silica, causes the material to become more refractory, and at the same time disposes the lead compounds present, to yield up the metal with greater facility in the subsequent operation. This base is employed also to effect the opposite change of rendering a refractory slag less so, but in much smaller quantity than when it is used, as the saying is, to *dry* the mass. The grey slag, which is thrown to the right, and which contains from a fifteenth to a tenth of its weight of lead, is subsequently smelted in what is called the *slag hearth*, while the richer material, consisting of semi-reduced ore, mixed with fragments of coke and clinkers, and termed browse, as already mentioned, is mixed with some slack, and reintroduced into the furnace. A brick of peat is placed before the nozzle of the blast-pipe, in order to spread the current, and the whole is heated for about a quarter of an hour, at the end of which the materials are raked out on the working-stone, where some lead is sweated from the mass, and a portion of grey slag separated. Some small coal and a greater or less quantity of lime are again thrown into the furnace, a square of peat is placed before the venthole, the browse is reintroduced together with a small quantity of fresh ore, and the furnace urged for fifteen minutes longer, when the material is drawn out as before, and the grey slags separated, as well as the portion of metal which becomes reduced. Thus every quarter of an hour the *browse* is returned into the furnace, with the necessary addition of fuel and fresh ore; and, at the same interval, some lead is separated from the mass on the workstone, and flows into the receiving-pot. The operation is continued uninterruptedly for fourteen or fifteen hours —termed the *shift*—in which time from one to two tons of metal are obtained. The furnace is then allowed to cool for some hours, before another shift is commenced. Lead prepared in this way is esteemed for its purity, which arises from the comparatively low degree of heat applied in its preparation, being inadequate to the reduction of any other metals excepting the lead and silver.

At Pezay, in France, the operations conducted in this kind of furnace are much the same as have just been described; but there is a division of the work, the first part being distinguished as the fluxing or melting, and the second as the sweating or eliquating.

The ore which is occasionally treated in the Scotch furnace, when it contains much carbonate of lead, is not subjected to a previous roasting, but at once submitted to the smelting operations described.

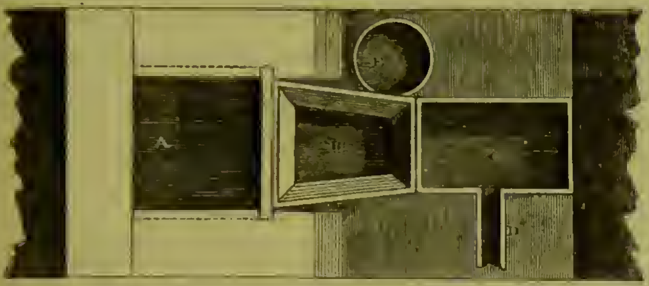
The Slag-Hearth.—In England, as well as at Pezay and other places, the slags from the reduction by the ore hearth, and also from the reverberatories containing a variable amount of metal, are reduced in what is called the *slag hearth* in the English establishments, and *fourneau a manche* by the French.

Fig. 325.



This furnace is seen in section in Figs. 325 and 326, in which A shows the cast-iron plate forming the base of the furnace; B, the pot or basin in which the lead is collected, and which is filled with cinders, *et cetera;* C is the tank containing water, and used to cool the slags which flow into it, after passing over the basin, B, and depositing therein the lead; and D shows a pipe which supplies the tank with cold water. The form of the furnace is generally that of a rectangular prism, twenty-six inches in length, twenty-two in breadth, and thirty-three in height. The plate of iron, A, forming the bottom, is slightly inclined to the front, and on each side of it are bearers, as in the ore hearth, for supporting the fire hearth, which consists of two stout plates of cast-iron about twenty-six inches long by twelve inches broad. By this arrangement a space of about five inches is left between these plates and the bottom of the furnace, and an additional height of two and a half inches is gained by placing upon them a row of firebricks. In every other respect this furnace differs but little from the ore hearth, only that the temperature is much higher in it than in the latter. From the basin, B, the accumulated metal flows by a pipe into the metal pot, E, whence it is cast into pigs.

Fig. 326.



At the Dee-Bank Works of Messrs. Walker, Parker, and Company, to which allusion has already been made, there are eight of these in operation for working off the slags from the reverberatory smelting furnaces. Peat is used to heat the furnaces when first set in operation; this is lighted in the usual way and the blast set working. The peat is surmounted by a layer of coke, and when the temperature rises to the melting intensity, a layer of the slags, or scoria, is introduced. After this the temperature is kept up without intermission, and the furnace is charged with successive layers of coke and slags as the matter sinks in the furnace. The materials enter into fusion ultimately; but before this change is effected, there is a deoxidation of the sulphate of lead in the higher part of the furnace, and a subsulphate or sulphide produced instead, which, acting upon the undecomposed sulphate, liberates the lead of both, the sulphurous products being volatilized. The oxide of lead which might also be produced by the reaction of the excess of lime present, is likewise reduced by the charcoal to the metallic state. By virtue of its gravity, the lead separated descends through the molten mass. The metal obtained in this way is never large in quantity, and is accounted of inferior quality, owing to the great heat at which it is produced, reducing other matters, such as iron, *et cetera*, and which are alloyed with the lead.

Smelting Silicious Galenas.—In many Continental localities where the galena is very silicious, a process of smelting is followed, different in its nature and characteristics from that which has been detailed, as well with reference to the reverberatories, as to the high furnaces. For the difference of treatment, a direct necessity exists, inasmuch as were such silicious galenas worked by the *method of reaction*, that is, roasted with the view of generating a quantity of sulphate of lead which might be made to react upon the unaffected sulphide, so as to precipitate the metal from both, a very serious loss would be incurred; because instead of inducing such a change by the fusing temperature finally applied to the ore, a combination of the oxide of lead and silica arises, and the silicate so produced, besides being difficultly decomposed, has no action upon the sulphide and sulphate of the metal, and, consequently, a large quantity of metal would pass off unreclaimed. The process adopted is founded upon the reduction of the sulphide of lead by metallic iron, whereby the negative element is transferred to the latter metal, and metallic lead separated, as shown in the equation:—

$$\underbrace{\mathrm{Pb\,S},}_{\text{Sulphide of lead.}} + \underbrace{\mathrm{Fe},}_{\text{Iron.}} = \underbrace{\mathrm{Fe\,S},}_{\text{Sulphide of iron.}} + \underbrace{\mathrm{Pb},}_{\text{Lead.}}$$

As is evident, the decomposition of the galena is perfect, and takes place in equivalent proportions, so that, by the use of twenty-eight parts of iron—one equivalent—one hundred and four parts of lead—also its equivalent—is produced.

At Clausthal, a quantity of ground and washed ore is taken and mixed with various other products, resulting from foregoing operations, together with a proportionate quantity of granulated cast-iron, and the scoria which are detached from this metal when working it under the hammer, *et cetera*, and the whole is fused in a small high or blast furnace, such as is represented in the annexed engravings. Figs. 327 and 328 show a front elevation and section, and Figs. 329 and 330 a side elevated section and plan. The shaft, A B, is about twenty to twenty-three feet high, and about three and a quarter in breadth at the widest part. Usually the shaft interiorly presents the appearance of two inverted crucibles, the lower one, or B, contracting towards the bottom, and the upper, or A, towards the top. At the

Fig. 327.

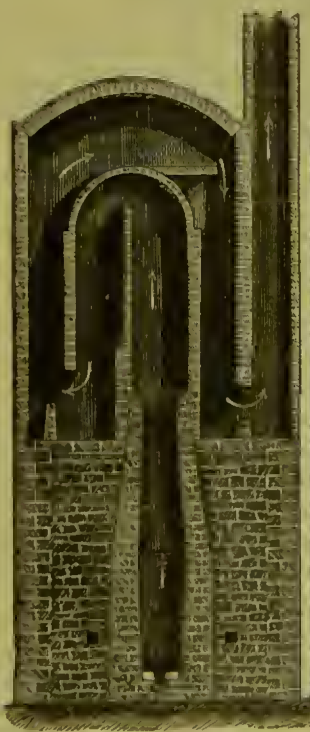
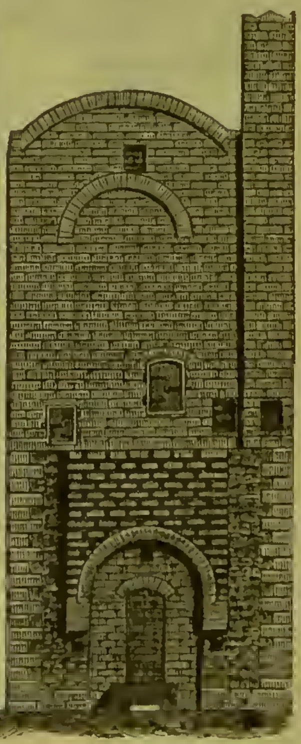


Fig. 328.



base of the shaft is found the crucible, the base of which is formed of two grit-stones placed so as to form a channel at their junction. Upon these stones a mixture of clay and charcoal is firmly pressed, so as to face the whole up to the furnace part, leaving a cavity in the middle, as indicated by C and D in the figures. An aperture connecting the crucible, D, with a second crucible, E, Fig. 330, by means of a gutter or pipe, permits the fluid matters in the former to run into the latter. The blast is introduced by two tuyeres placed in the face opposite the trymp. The mineral is charged on the tuyere side, and the fuel on that which is opposed to the blast, and as the heat advances, the scoriæ which attach themselves to the nozzle are quickly cooled, and form an elongation of the latter of about three inches, which enters into the furnace. This incrustation, called the *nose of the tuyere*, is of importance, inasmuch as it conveys the blast to the fuel, and all the oxygen being combined in this, oxidation of any of the mineral constituents is prevented. Indeed, the proper management of the *nose* requires all the care of the smelter, as upon it much of the success of the reduction depends. The superior part of the furnace is kept at as low a heat as possible, in order to prevent the volatilization of the sulphide of lead. But, in addition to this precaution, the volatile product traverses from the mouth of the furnace, by a number of chambers, before it enters the chimney, so as to intercept the *lead ashes* which volatilize. These chambers are emptied periodically, and the product smelted with others in the usual way. In working this furnace the melted matters flow out continually into the crucible, D, and when full the connection with E is opened, when the contents are transferred to the latter, the metal forming the under part, and the slags the superior. When the aperture becomes closed by the cooling and solidification of the scoria, the obstruction, is removed by an iron bar and hook. The scoria which covers the metal in the outer crucible, is composed of a subsulphide of lead, sulphate of lead, particles of iron, and other substances. It is called *the first lead matt.* After being removed by an iron hook from the bath, the metal is poured through a metal cullender or sieve, to separate fragments of slag, and then cast into pigs.

Fig. 329.

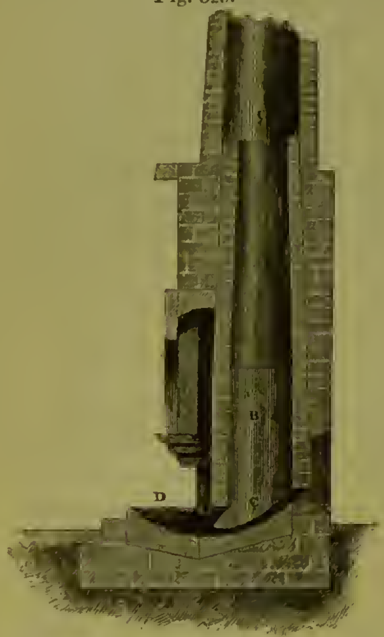
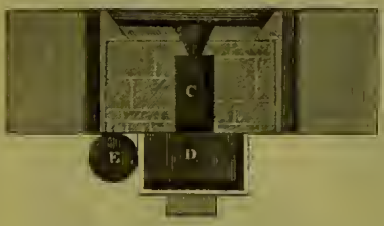


Fig. 330.



If the scoriæ be poor in lead, they are rejected, but the richer products are retained to be worked up with a further quantity of roasted ore; but sometimes they are collected till there is a sufficient quantity to be reduced separately.

The original mixture is composed generally of—

34	parts of mineral, containing about twenty-four of pure galena.
4 to 5	parts of the debris of the cupelling furnace, and impregnated with litharge.
1	part of the first litharge—called *abstrichs*—formed in the process of cupellation.
39	parts of scoria obtained from the first fusion of the mineral, *et cetera.*
4½	parts of granulated iron.

REGNAULT states, that this mixture yields nineteen parts of metal, and seven or eight parts of first matt, containing two and a half parts of metal.

At Tarnowitz in Upper Silesia, the rich mineral obtained there, and containing about eighty per cent. of lead, is treated in a blast furnace like the last-mentioned, with about twelve per cent. of old iron or shot. and as much of the rich matt from the preceding as is thought necessary, together with thirty-six per cent. of the scoria from the same operation, to confer fusibility. About fourteen per cent. of coke are consumed, and the products are sixty per cent. of lead, and twenty-four of matt rich in lead. Most of the scoriæ are rejected. The campaign, or smelting period, continues six days uninterruptedly, in which time thirty tons or more are smelted on an average. The poorer ores, yielding only fifty per cent. of lead are smelted in a high-blast furnace.

In this case the additional matters are, for a hundred of the ore—

32	parts of	matt from the smelting of rich mineral,
12	,,	debris of cupelling furnaces, *et cetera.*
10	,,	scales from the iron forges, and
24	,,	scoria from the refining.

Forty-three per cent. of coke are used, and the produce of metal amounts to about forty per cent. of the ore operated upon. Each smelting campaign lasts a week. and the produce during this period averages from twenty to twenty-two hundreds of metal.

Generally speaking, those minerals which are rich in silver, and contain large amounts of gangue of a silicious nature, when subjected to the preceding treatment, give a matt which still retains a portion of the noble metal, and on that account is reserved to go through a second fusion.

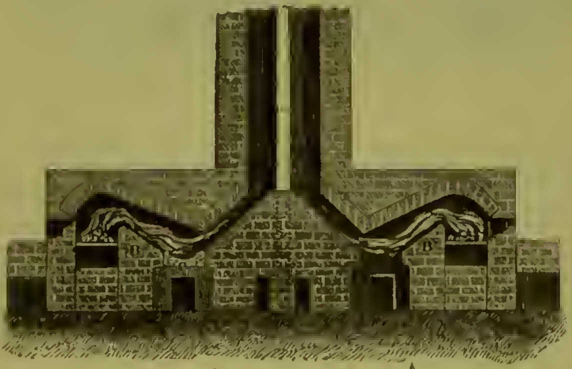
PURIFICATION OF LEAD.—In almost every case, the lead which is obtained from galena and other ores contains more or less silver, varying, in the English ores, from twelve or more ounces per ton of lead smelted to two ounces or less. In other varieties of lead ores, such as those worked in many establishments on the Continent, the yield is greater, averaging as much as nine per cent. of the lead. When the precious metal is in so large a proportion, the lead is termed workable metal, that is, in a fit state to be cupelled for the silver; but as most of the lead produced in Great Britain was found to yield only quantities averaging, for the richest, ten ounces per ton or thereabouts, and often as low as two, the trouble of recovering this was thought to be more expensive than the gain in silver, and consequently it was left in the lead. A very simple and unfailing method, however, is now pursued, founded upon a property of the alloy of lead and silver, whereby such lead as contains only about two ounces of silver to the ton of metal can be economically worked for the recovery of the silver. To this process reference will be made presently. Besides silver, there are other impurities found in much of the lead produced on the Continent—more especially in such as is reduced from ores containing the tersulphide of antimony, blende, and the like—owing to an alloy of these metals with the lead being formed. Of course these metals destroy in a great measure the characteristic properties of the lead; so much so, that sometimes it cannot be employed, in many of its applications, till it has been submitted to a process of purification; and when the impurities alluded to exist only in very small quantities, the quality of the metal is so deteriorated, that it will not resist the air or liquids, or work under the roller with satisfaction. Such impurities are occasionally detected in small quantities in some of the English lead; seldom arising from the native ores, however, but rather from parcels of foreign imported mineral. It will be evident that the latter impregnations are much more injurious than silver; for, notwithstanding that this metal renders the lead hard under the roller, it enables it to resist the action of the air better; whereas the other impurities mentioned destroy, to a great degree, the natural power of the lead to resist the air. Traces of iron are frequently found in tho lead, when ferruginous gangue or pyrites is associated with the ore; the iron is never removed, however, by any special process, owing to the amount being too minute; nevertheless, the quantity, even though it be only a small decimal mal of a per cent., is found to be highly injurious in the manufacture of red lead and carbonate of lead from the metal.

The method adopted for removing the antimony, tin, copper, zinc, and other foreign matters, is often tedious and expensive. It is founded upon tho oxidation of those metals, and the separation of the dross of mixed oxides from the lead. To effect this, the smelted metal is re-melted in a reverberatory furnace, through which a copious draught is instituted, and allowed to remain in this state, the scum of oxide being removed from time to time till the most part of the easily oxidised impurities are separated.

To purify the metal, a variable period is required, dependent upon the proportion of the impurities present; hence it happens that whilst some kinds are sufficiently febrnated in twelve hours or thereabouts, other kinds require a prolonged treatment of several weeks. The dross is a mixture of the oxides of the metals present as impurities, and of lead; and from the color, when drawn out, an opinion is formed as to the extent of the purification. In addition to this, however, the refiner takes out a sample in the ladle, and pours it into a small mould; and, as it cools, he observes the change on the surface, and concludes accordingly. When the impurities are nearly removed, the surface of the assay assumes a peculiar flaky crystalline appearance,; and as soon as this is recognized, tho bath is cleaned from the dross; and the metal, retaining the whole of the silver originally present, is allowed to flow out into the pot, from which it is afterwards ladled into the moulds.

If this lead, thus deprived of the brittle and easily oxidised metals, be sufficiently rich in silver, it is submitted to a process of cupellation in a furnace similar to that represented in the annexed drawings—Figs. 331 and 332—which represent it in plan and section. In these A is the fire; B, the bridge; C, the cupel, which is movable, and composed of a sash or frame of iron bound by a rim of the same; presenting at the under part four transverse bars on the plan of that described at page 284—Fig. 229. The refractory materials, consisting of bone-ashes and very fine *cinders*, aro placed on, and well beaten together. After the whole is dried, it is inserted in the furnaco as represented. E E are openings, either for introducing the pigs of rich metal or the melted alloy into the cupel; F F, means for forcing the blast; but in large works, where several refining furnaces are in operation, the air is urged upon the metal by means of a fan, driven by steam-power, and connecting pipes. The oxide of lead or litharge, produced in the course of the operation, falls into a receptacle, D D, beneath the cupel, and is periodically removed.

Fig. 331.



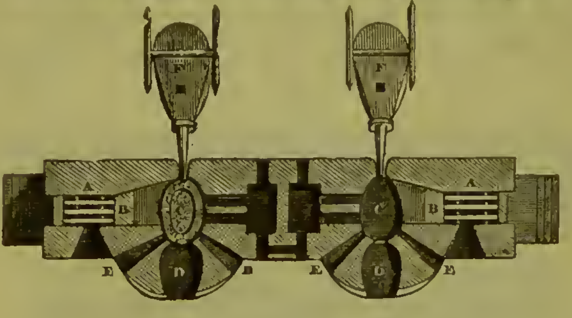


Fig. 332.

The furnace which is in use at Clausthal in the Hartz, is shown in Figs. 333 and 334, next page. Fig. 333 is a front elevation; Fig. 334, a plan on a level with the fire-bridge and tuyeres. A glance will be sufficient to show that this is a kind of reverberatory furnace, the bed of which is circular, and hollowed in the middle a little more than ordinary. The fire-grate, F, is shown at the side, with the draught and ash-holes, E. *a a*, are the apertures through which the air is blown into the furnace for the oxidation of the lead, which is introduced at the opening, P, in the form of discs; the lead, thus deprived of its metallic characters, is emitted as litharge in the fused state through the opening, O, and falls upon the floor of the refinery, or into pots. A riveted plate-iron dome covers the sole of the furnace; it is furnished with tackle, as shown in the drawing, by which it can be raised at pleasure. Much attention is given to the formation of the sole of the furnace. The first bed is composed of scoria, well beaten together, and hollowed as a sphere; and upon this a similarly-shaped one, of bricks placed closely together, is formed; and a third overlays tho latter. It is constructed of *marl*, and beaten down firmly; but in the most cases, it requires renewal at every fresh charge; tho old material, which had become saturated with litharge, being employed afterwards with the matt and mineral in the smelting operations, as already detailed.

Fig. 333.

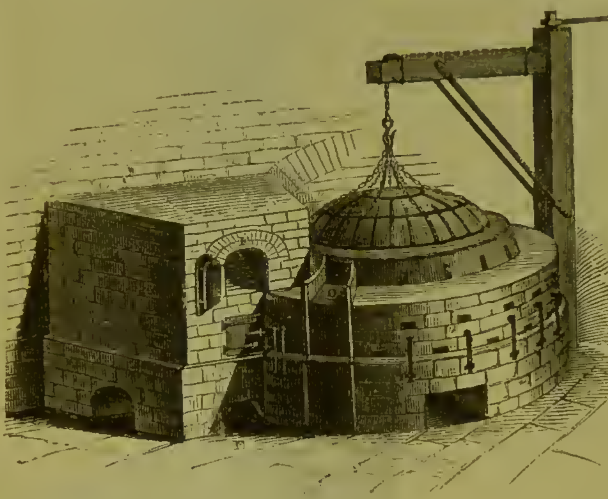
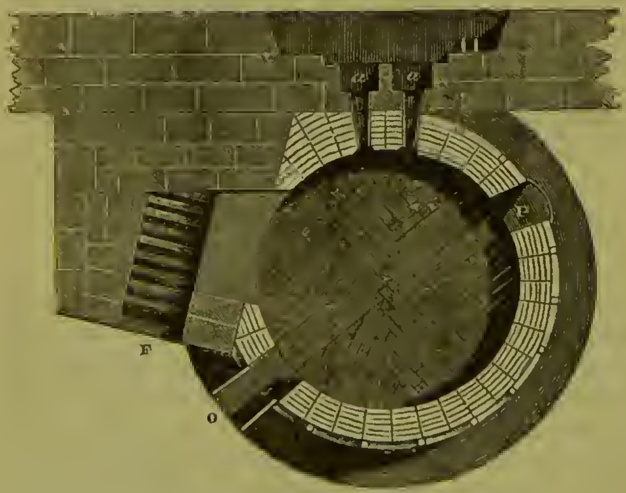


Fig. 334.



The furnace being in order, the charge of metal, amounting to one hundred and sixty quintals, is introduced, and the fire lighted; in a short time the lead begins to flow, and, as soon as the whole has melted, the blast of air through the tuyeres is forced upon the bath. The melted lead under this influence rapidly oxidises, and becomes covered with a blackish coating of oxide of lead, mixed with other impurities, and which, when removed, constitutes what is termed the abstrichs. This coating of oxide does not fuse, but forms a solid covering, which would impede the oxidation of the lead, unless removed. Some charcoal powder is thrown in upon the metal from time to time; and, by the aid of a bar of wood, fixed crosswise upon the end of a bar of iron, the workman draws the abstrichs towards the door, O, through which they fall upon the floor of the refinery. After the removal of these matters, the blast is kept up, and fusible litharge begins to appear, and flows out at the aperture beforementioned; the first portions, however, are very impure, owing to other foreign matters existing with the lead, and are consequently retained, to be *revivified* in the reverberatory or blast-furnace. After a while the product assumes a better color, indicative of its being purer; and, when it has appeared of the proper shade, it is collected for marketable or commercial litharge, and sold as such. When this happens, the blast is urged to effect the removal of the lead as quickly as possible, and the force of the stream of air kept up, till the entire of this metal is removed, and a disc of metallic silver remains.

The proper period for arresting the oxidation of the lead by the blast, is indicated by what is termed the *brightening* of the assay. Whilst the oxidation proceeds, the appearance of the metallic bath is much more luminous than the walls of the furnace; this arises from its temperature being more elevated, for not only does the bath acquire its heat from the fire, but also from the oxidising material, which develops much caloric. As soon, however, as the lead is removed, or nearly so, the temperature of the metallic residue falls to the mean degree of the furnace, and instead of remaining very brilliant, as it was before, it appears tarnished. On the other hand, when the last portions of lead become oxidised, very little remains upon the surface of the bath besides a pellicle of melted litharge, which diminishes rapidly, and presents in succession all the rays of the prism, and, finally, is torn asunder when the surface of the unoxidisable metal makes its appearance. It is this rapid succession of optical phenomena to which the above epithet of brightening is applied.

As soon as this appearance of the bath is observed, the workman throws some hot water on the surface of the disc of metal remaining, and after that some cold water, both of which rapidly reduce the temperature so much as to enable him to remove the silver. This residue is not absolutely pure, however, but contains from one-twelfth to one-sixteenth of its weight of lead, which is removed from it afterwards in the *refining* process, which will be described under SILVER. The hundred and sixty quintals of lead obtained from the schlich at Clausthal afford quantities varying from three hundred and ninety to four hundred and fifty ounces, according as the metal is obtained from the crude schlich or roasted matt, which is generally the richer. Thirty hours are occupied in cupelling the charge. The litharge which is produced towards the close of the operation contains a notable amount of silver, and on this account it is separated from the rest with the view of afterwards recovering the precious metal.

The abstrichs, cupel bottoms, and rich slags are afterwards passed through a blast furnace, whilst the yellow and red litharge find their way, after being finely ground or reduced to powder, into the market. Sometimes, however, the better quality of litharge is reduced. This depends on the demand and the relative value of the metal and the litharge. Generally the lead produced from the fine litharges commands a better price, owing to its being very pure. Abstrichs and the first litharge that is produced in the cupellation are frequently smelted by themselves, especially when they are of an antimonial nature; and the impure lead thus produced is sold at a lower figure for the manufacture of shot.

Pattison's Process.—It will be evident that the oxidation and reduction of lead, when it contains only the one-thousandth of its weight of silver, would be unremunerative if this quantity were to be recovered by the method just described; and much less remunerative would be the cupellation of metal containing not only not the one-thousandth part, but as low a proportion as one-thirty-thousandth part of silver. By a method, however, discovered by H. L. Pattison of Newcastle-on-Tyne, so small a quantity as one ounce of silver per ton of lead may be recovered with advantage. This beautiful process—like many others the result of an accident—was discovered in 1829. It is founded on the circumstance that an alloy of lead and silver, when cooled with occasional stirring, so as to be at or near the point of solidifying, crystallizes to some extent; and the part so crystallized is found upon examination to contain a very much smaller quantity of silver than the fluid matter which remains, or than the original alloy.

The application of this principle, which is known as *Pattison's process,* is extremely simple and manageable. Generally a series of eight or ten cast-iron pots, each capable of holding about five tons of molten lead, are arranged in a gallery of brickwork with a fire-place beneath each. The middle one of the range is charged with *original* lead, varying, as to the quantity of silver, from twenty or more ounces per ton to two. When the whole is melted the fire is withdrawn, the surface of the metal is carefully skimmed, and the fluid matter stirred by means of an iron spatula. After a brief interval, crystals begin to form and fall to the bottom of the pot, whence they are removed by another workman with a perforated ladle; all the fluid metal being separated by shaking the contents of the latter, which the workman effects by springing the handle on the edge of the pot. These crystals are deposited in the next pot, to the *right* of that in which the metal is first melted, in proportion as they are formed, till about the four-fifths of the weight taken has been transferred. The remaining one-fifth, which is now considerably more enriched with silver than at first, is ladled out into the first of the series towards the *left* hand. A new charge is again put into the middle pot, and transferred in the same way to the right, which may be designated No. 2. When enough of metal has been ladled into the latter to constitute a charge, it is in turn heated, and the crystallized lead melted, after which the process of separating the lead, after it has crystallized, is proceeded with as before, allowing about a fifth to remain, but which is transferred back to No. 1. In this way the operations are conducted, till the whole of the pots come to be filled with metal holding more or less silver, according to their position in the series, at which time the work may be carried on with the whole, the poor metal passing always to the *right* from the extreme *left*, and that which is rich in silver traversing the pots in the opposite direction. Hence it follows that those to the right must contain metal which is being gradually deprived of silver, while that in the series to the left, must become richer in silver as they recede from the middle one.

During the working of the metal in the vessels, the ladles which are employed are apt to become chilled, as well during the draining of the crystals as when they are withdrawn from the fluid metal for any length; in either case the perforations being stopped by the fluid alloy solidifying in them, and to prevent or remedy this the temper pots are employed. These are about two feet in diameter, and filled with melted lead, the temperature of which is much more elevated than that in the working-pots, so that when the ladle is cold, or its grate obstructed by pellicles of the cooled metal, its immersion for some minutes in this pot will heat it to the proper degree, or free it from the obstructions referred to. Very little attention is necessary to comprehend how the purification from silver may thus be effected, and how the operation, with some slight attentions, cannot fail to be successful. The principal point to be attended to, apart from keeping the metal well stirred with the slice, and carefully removing the crystals, is the regulation of the heat, and which should merely border on the melting point of lead. When beyond this, very few crystals will form, and the process will be slow; practice, however, is the best guide in this particular. The following analyses of the assortments in this process may not be uninteresting:—

	Skimmings.	Skimming reduced.	Market crystals.	Market lead.	Rich lead from crystallizing process.
Lead, ...	98·10	99·72	99·9	99·9	99·8
Antimony, ..	0·28	trace	trace	trace	trace
Copper, ...	trace	trace	trace	trace	trace
Iron, ...	1·40	0·28	0·1	0·1	0·2
Lime, ...	0·22	—	—	—	—
	100·00	100·00	100·0	100·0	100·0

It is to be supposed, however, that a greater or less proportion of silver is contained in all the above, although it is not taken into account in the analyses. The concentration of the alloy is not carried on beyond three hundred ounces per ton at the works above-mentioned. When the silver has accumulated to this proportion, the rich lead is cast into bars about two inches square, and is known by the term *lead riches.*

Pattison's invention is now applied in almost all the lead works of the United Kingdom, and within the last ten years, it has been adopted in the principal lead foundries of France, Spain, and Prussia.

Cupellation of the lead riches.—This operation is performed in a furnace of the reverberatory class, having a contracted bed of a particular construction, and designated the cupel, or *test.* This apparatus, with the whole process of cupellation, is fully described at page 284, under the article GOLD. At the smelting works of Messrs. WALKER, PARKER, and Company, where the *riches* holding about three hundred ounces of silver to the ton are cupelled, the process is continued in the same furnace till the last traces of the lead are removed, and the silver is left pure. In the eight refiners at this establishment, there are produced weekly from six to eight bars of silver, each weighing a thousand ounces. The litharge which does not find its way into the market, is reduced in the reverberatory furnace, by mixing it with small coal or slack, and eliquating it on the bed, which is coated with slack to the depth of two or more inches. In the refining process, the products obtained besides the silver have the following composition at the different stages of the process :—

	Unfallen litharge, common.	Fallen litharge, common.	Fallen litharge, best.	Test bottoms.	Fumes from refining furnace
Oxide of lead,	99·7	99·6	99·7	59·60	97·00 carbonate of
Sesquioxide of iron,	0·3	0·4	0·3	trace	1·10
Teroxide of antimony,	trace	trace	trace	1·06	0·16
Oxide of copper,	trace	trace	trace	trace	—
Lime,	—	—	—	20·00	trace
Magnesia,	—	—	—	0·40	—
Phosphoric acid,	—	—	—	18·52	0·10 alumina
Silicious matter,	—	—	—	0·44	1·64
	100·0	100·0	100·0	100·00	100·00

USES.—Such are the processes resorted to for the extraction of lead from its ores; but before it finds its way into the industrial arts, it is converted by mechanical contrivances into the necessary forms. These are, for the most part, sheets and tubes; the former being employed largely in architecture, for protecting the roofs, *et cetera*, of buildings, for the lining of tanks in which water is retained, for the construction of evaporating pans, sulphuric-acid chambers, and numerous other purposes. Pipes, on the other hand, find their application in conducting and distributing water, liquids, gases, *et cetera*. And, latterly, lead has been spun into wire, in which state it has been found useful for horticultural purposes, by the resistance which it offers to atmospheric influences. It also enters into various other compounds of a metallic nature, and by its peculiar properties, confers great advantages.

Lead is manufactured into sheets by means of rolling, combined with pressure. The melted lead is cast into a heavy plate six square feet, or more, and about six inches in thickness; and when sufficiently cold to admit of its being lifted by the crane, it is placed on the bench where the heavy iron rollers are situated, and passed under them repeatedly, backwards and forwards, till it is reduced to the desired thickness. By means of screws the rollers may be adjusted at any required distance from each other. At the rolling department of the Dee Bank Works the heavy cylinders are eight feet four by twenty-two inches diameter, and the lead is reduced sometimes to only the sixty-fourth part of an inch in thickness.

The works at Chinese Lead Valley—the pipe-founding department of the same firm—are on a similar scale of magnitude and elegance; and the old process of producing pipes by drawing and rolling is quite discarded. Hydraulic pumps and properly-arranged dies—of which there are a series, producing lead pipes from the smallest gas-pipe to conduits three and four inches internal diameter—may be seen at work, and capable of producing any desired length of piping, of the most regular and homogeneous thickness and quality throughout. Without going further into the details of these very beautiful mechanical contrivances, the subject may be here closed so far as the smelting, purification, and manufacture of lead is concerned.

ALLOYS.—Lead enters into the construction of several alloys, many of which have been already referred to—see ANTIMONY, BISMUTH, *et cetera*, *ante*;—and pewter, or solder, so largely employed by the plumber, is a combination of this metal and tin, in the proportion of two parts of lead to one of tin; sometimes, however, the proportion is varied, according to the requirements of the plumber.

Shot-metal.—Another alloy of lead is in very general use for lead-shot, and is a combination of this metal with arsenic. Shot-metal generally contains also portions of antimony and iron; since lead which is of inferior quality, owing to impregnations of the latter kind, is reserved especially for this manufacture. Arsenic, however, being the recognized alloying metal, the others are not noticed, although their presence affects the proportions in which the arsenic is to be added. Generally, the limits are from three to eight or ten parts in a thousand; the lesser quantity being employed as the lead is more ductile, and the larger when it is hard. The arsenic may be incorporated with the lead while in a state of fusion, either in the form of arsenious acid—*white arsenic*—or of orpiment—*sulphide;* and by the reaction which follows, the arsenic is reduced to the metallic state and combined with the lead; while a portion of the latter is thrown off as sulphide or oxide of lead, according to the nature of the arsenical body employed.

To prepare shot-metal, a quantity of lead, amounting to two or three tons, is melted in a pot; and when the heat has been pretty well raised, the surface of the metal near the rim of the pot is strewed with ashes or powdered charcoal, and the arsenic is introduced in the centre, and stirred with the metal briskly; the pot is then covered, and left so for some three hours. During this time reduction of the arsenical compound takes place, and an alloy of arsenic and lead is formed. With a good quality of lead, the proportion varies from twenty to twenty-eight pounds of arsenic to the ton of metal. This quantity, however, is not combined; for, on removing the cover from the pot, and stirring the whole with the slice or spatula, a large quantity of the arsenic is thrown off with the litharge which is produced. Sometimes orpiment is used, and in small but successive quantities, stirring after each addition. The alloy is tried by letting a little of it fall through a perforated cullender into water; if the particles thus produced present a lenticular appearance, the proportion of arsenic is too small; but when they are flatter, or hollow in the middle, or elongated, it is an indication of there being a deficiency of arsenic—the proper degree of saturation is arrived at when the globules are round.

When, by this proof-test, it is judged that the alloy is properly saturated with arsenic, the whole is cast into bars, and raised by an endless chain to the top of a high tower, where it is melted in a small pot, and cast in perforated cards fitting into a frame in the centre of the tower. Some expertness is requisite on the part of the founder in maintaining the lead at the proper degree of heat, and also in allowing a film of oxide to form on the interior of the card, through which, in passing, the metal becomes disposed into grains as it parts from the card. Though the management of this part of the operation is deemed important, doubtless it serves only to cool the metal; for if it were to pass through in a too liquid state, it would assume an elongated form, and not globular. There are, of course, for the various kinds of shot, special cards, with perforations corresponding to the size; only that the aperture in the card is much smaller in diameter than the globule of metal which is formed by passing the metal through it. At the base of the tower is a circular basin, five or six feet deep, containing water, and into this the shot falls. When the smaller shot is being cast, the temperature of the metal is somewhat higher than for the larger kinds, such as those known by the letters A, A A, and A A A; B, B B, and B B B; with the latter the metal is said to have acquired the proper temperature when a straw plunged into it will not char, but acquires a perceptible brownish color. The cards used at the Chester Works are rectangular, and about twelve inches by eight; in other establishments hemispherical disks are used for casting the shot; but these are not so convenient as the flat-bottomed cards.

The next step in the process is the removal of the shot from the well, and drying it on a rectangular stove, the top of which is of cast-iron, heated by a fire; on this it is moved about till all traces of moisture have disappeared. It now presents a greyish-yellow aspect. To assort the grains according to the respective sizes, the dried article is put into a long perforated copper cylinder, the perforations corresponding at regular distances with the size of the shot; and beneath such divisions boxes, marked Nos. 13, 12, 11, 10, *et cetera*, for the reception of such as fall through, the smallest being first, and the larger approaching the further extremity, where the kind indicated by B B B are received. A revolving motion is given to this cylinder; and besides, at each revolution, a clapper is made to fall against it on the top surface, so as to knock out any grains which may remain in the perforations. During this process the appearance of the shot is slightly altered on account of the friction; but still it retains its dull, grey aspect. To give it the bloom, it is introduced into a cylinder by a door, together with a small quantity of blacklead plumbago, and the whole made to revolve for some time; and when taken out, it is found to have assumed the well-known dark-grey lustre or polish peculiar to this article.

Before it is ready for use, however, it has to undergo another treatment, by which the defective grains are separated, and none but the truly circular find their way into the sportsman's belt. This is done by a very simple, but ingenious and effective contrivance. An inclined plane, slightly levelling to the sides, with a box or receptacle for the shot to be tested at its head, and the central portion of which is perfectly level, serves to make this assortment. A small aperture in the bottom of the box, and partly closed by a slide, allows the shot to roll out upon the middle of this table, after which it descends the incline. If the grains be perfect, they move on the middle space till they finally fall with a bound into the box placed in the front for their reception; but the least inequality causes them to deviate towards the sides, where they drop off into the receptacles ready for their reception, whence they are removed to be again melted and recast. The perfect shot is put up into twenty-eight pound bags or packages, ready for the market. In the establishment of WALKER, PARKER, and Company, about ten tons are manufactured weekly on an average; the shot-founding department is unique in the extreme.

Lead is capable of entering into combination with all the metalloids in one and multiple proportions, and of giving rise to bodies which are saline or salifiable, according as the radical combined is capable or not of generating salts. Thus, with chlorine, bromine, fluorine, and sulphur, salts are formed; whilst with oxygen, it constitutes several compounds, of which one is salifiable, others neutral, and finally, a third class, under peculiar agency, manifest acid properties.

OXIDE OF LEAD—Syn. Litharge—*Massicot*, *Litharge*, French; *Gläss*, *Bleioxyd*, German.—There are several compounds of lead and oxygen known to chemists, such as the *sub* and *prot*oxides, the *sesqui* and *per*oxides; but all are not of equal interest to the manufacturer. Indeed, of these only the protoxide and the peroxide of lead have been recognized as articles of commercial industry, although, for the most part, more or less of the sesquioxide finds its way adventitiously into both articles.

The protoxide may be prepared in the pure state by heating carbonate or oxalate of lead at a dull red heat in a crucible, in which a current of air is made to circulate, or in an open dish. Here the salt radical is dispersed, and there remains a straw-yellow substance, which is pure oxide of lead, provided the salts submitted to the process contained no adulterants. When the temperature at which it is produced is elevated, it assumes a brownish-red color, which in part disappears as it cools. It is very heavy, and on being fused and allowed to cool, it forms itself into crystals, which, if the refrigeration be sudden, appear as scales; but if gradual, they assume the form of yellow, translucent, hexagonal tables. Oxide of lead is slightly soluble in water, producing solutions which have a feeble alkaline reaction. In potassa or soda liquor, the oxide is easily dissolved, and in this reaction doubtless assumes the nature of an acid, and produces a plumbate of the alkali. If, however, the solution be allowed to remain for some time exposed to the air, the heavy oxide separates completely, and is ultimately found in dodecahedral crystals. It possesses very powerful basic properties, and is capable of producing neutral saline bodies with the weakest acids. It also combines with many of the acids, in proportions to constitute soluble subsalts, which manifest an alkaline reaction. In the heat it vitrifies boracic and silicic acids, whence its use in the manufacture of glass, pottery, *et cetera;* with oils, also, it seems to enter into peculiar combinations, which confer on them the property of drying rapidly on exposure to the air. Oxide of lead is readily decomposed when heated with carbonaceous or sulphurous matters, metallic lead being formed, and carbonic or sulphurous acid. When obtained by precipitation of the nitrate or acetate of lead, by means of an equivalent proportion of potassa or soda, it assimilates water, forming a hydrate, which rapidly absorbs carbonic acid from the air. Oxide of lead is highly useful to the chemist, as it constitutes definite salts with most organic acids, and thus enables him to isolate the latter in his researches, or bring them into a convenient form, for the determination of their equivalents and constituents. Being so generally employed, it is evident that the greatest attention should be given to the determination of its equivalent. Such has been the case, and repeated estimations of its constituents and combining weight have led chemists to fix the latter at 112, its composition being as follows:—

	Centesimally.
1 Eq. of metallic lead, ...	104
1 Eq. of oxygen, ...	8
1 Eq. of oxide of lead, ...	112

The anhydrous oxide is represented, therefore, by PbO, and the hydrate by PbO, HO.

The preparation of oxide of lead, on the large scale, is effected by heating metallic lead in the air, and removing the film of oxide which forms upon it. The first stage in the manufacture of minium is the preparation of this oxide; for, as stated, the metal is oxidised, at a low temperature, with a current of air passing over it. This is the *massicot*, but it does not find its place in the market, although it is more adapted for many applications than the other form of the same body known as litharge. This may arise from the circumstance that, for the production of the massicot, an especial oxidation of the lead should take place, and at some expense; and besides, being finely divided and friable, it rapidly attracts carbonic acid from the air, and passes into the state of carbonate. On the other hand, the litharge is obtained as a secondary product, the production of which involves the manufacturer in no extra costs, and it resists air and moisture much better than the massicot.

Litharge is obtained by the oxidation of lead, raised to a high degree of heat by a blast of air, the temperature being so elevated as to fuse it. When the metal is pure, the litharge which it yields, with the exception of the first skimmings that constitute the abstrichs, is of good quality. Obtained according to this treatment, litharge is a yellowish, or yellowish-red, compact substance, crystallized in six-sided plates, and semi-transparent. It was customary to designate the yellow and reddish compounds by the terms *silver* and *golden* litharge, from the supposition that the latter contained some precious substance, to which the difference of color was owing. It is well known, however, that a slight superoxidation of the lead, which takes place at a lower heat or during the cooling, when much exposed, is the only difference. Litharge is used in painting as a pigment, for the production of acetate of lead, and sometimes in glass and pottery establishments.

Minium, or *red lead*, is another oxide which forms a special branch of manufacture, and one which, to produce a superior article, requires much care in the operations, and also in the selection of the materials. The purest lead is required for this manufacture. If it contains antimony, iron, silver, or such substances as are met with in inferior qualities of metal, the minium which it affords is never of a good color; besides, it is rejected by the manufacturers of flint-glass, owing to its giving the metal a peculiar dulness, which they endeavor to avoid. The metal selected from the products of the purest ores is melted in a reverberatory furnace, with a spacious hearth or bed, ten feet by seven, and having a high bridge and arch, so that the flame and gases revolve from the latter to the metal over the entire space. The fire is never urged to render the interior hotter than a very dull redness. In consequence of the air passing into the furnace through the fire, and by the other apertures, a covering of oxide forms on the surface of the bath; this is raked aside by the workman, and a fresh surface exposed. which in a short time becomes coated as before, and cleared in the same way. This operation, which is called the *drossing*, is continued till the whole of the lead is oxidised, and a yellowish powder of oxide results. The process occupies about twenty-two hours. As the massicot, or litharge, is increased in quantity, it is carefully disposed into channels for the purpose of allowing contact of the metallic portion with the air, to favor its oxidation. After the metallic character of the lead introduced has disappeared, the oxide, or dross, is spread out on the sole, and turned occasionally, in order that any particles removed during the drossing in the semi-metallic state, or in that of suboxide, may be wholly converted into litharge. When completely oxidised, it forms a layer of two and a half to three inches thick on the bed of the furnace. At this period the powder is raked out into iron waggons at the working door, and conveyed to the coloring furnace, which is in every respect similar to the last, only that its temperature is somewhat lower. Here it is spread on the sole in a layer, and left exposed to the oxidising effects of the air passing through the fire in a partly undecomposed state, and also to that which enters at the doors, which, unless the temperature be too low, are left half or quarter part opened. To expedite the oxidation—to which the tint is to be attributed—the surface is renewed frequently, and sometimes enlarged by artificial channels, made in it with a pronged rake. Great attention is necessary to maintain the heat of the furnace at its due degree—that is, somewhat below dull redness, or between 550° and 600°—also, in exposing a fresh surface till the proper shade of color is attained.

Forty-eight hours are occupied at the Dee Bank Works, where a remarkably fine article is produced. The *red lead*, which now presents a beautiful bright-red hue, is removed, ground under iron disks, circulating in a revolving flat iron tray, and packed in casks for the market.

Minium has a very doubtful composition, and is regarded by many chemists as a mixture of protoxide and of sesquioxide of lead $Pb\ O, Pb_2\ O_3$, whilst others maintain that it is a mixture of oxide and peroxide, the latter acting as the negative radical of a salt $2\ Pb\ O, Pb\ O_2$; and some hold that it is neither one nor the other, but a compound containing four equivalents of metallic lead, and five of oxygen, and which may be represented by the formula $Pb_4\ O_5$ or $3\ Pb\ O, Pb\ O_2$.

Minium is employed largely as a pigment in the paper-hanging manufacture, to communicate a rose, orange, and aurora tinge; for painting also it is in general use, and in the manufacture of glass and many kinds of pottery-ware, it is an indispensable ingredient, from the property it possesses of forming vitrifiable compounds with silica and alumina, which unite with the other silicates of the glass and ware, and thus render the body perfectly homogeneous.

There is another oxide of lead, known as the puce-colored oxide, which has not a general application, but is useful sometimes in analytical chemistry. Its gravity is 8·902 at 98°, and its composition

		Centesimally.
1 Eq. lead, ...	104	86·62
2 Eqs. of oxygen, ...	16	13·38
	120	100·00

Symbol $Pb\ O_2$. This body does not combine with acids; it is readily decomposed in the heat into oxygen gas, and protoxide of lead.

The salts of lead, important in a manufacturing sense, are the carbonate, the acetate, and chromate; the sulphate is sometimes prepared. Of these the acetate has been already described—See page 43, Vol. I.—so that only the others require to be noticed.

CARBONATE OF LEAD.—Syn. *White lead—Ceruse,* —*Blanc de plomb, Blanc de ceruse, de clichy,* French; *Bleiweiss, Kohlensaures Bleioxyd,* German. This substance is found in nature in small quantities, mixed with other compounds of the metal, in lodes of lead minerals—for instance, in Cumberland, in Scotland, in the Hartz, and in Bohemia; it is also found in many departments of France, such as at Saint Maria-aux-Mines in the Vosges; at Saint Saurier in Languedoc; at Poullaouen in Brittany, *et cetera.* Large deposits of it have been discovered in America, as at Mine a là Motte, and other districts.

In all these localities it generally happens that the carbonate is found associated with other minerals which constitute the bulk of the lode. In these cases it is almost always in the crystalline state, the figure being derived from the rhomboidal prism in some varieties, while other kinds appear as an agglomeration of very minute particles; and it is occasionally found in compact masses. Almost every variety is white or brownish-yellow, transparent, and very refractive, having a specific gravity varying from 6·070 to 6·558. The natural product is never employed for any of the purposes to which white lead is devoted in the arts, and hence all that is consumed in this way is of artificial production.

Preparation.—Pure carbonate of lead may be prepared by precipitating a solution of pure acetate, or of nitrate of lead, with another of a carbonate of an alkali, filtering off the solution, washing the residue thoroughly, and subsequently drying the mass. So obtained, it is a white powder almost insoluble in water, but dissolved with evolution of carbonic acid in nitric, hydrochloric, acetic and other acids, which yield with this base soluble salts; those salt radicals, which constitute with the metal or its oxide insoluble salts, decompose the carbonate, set free the carbonic acid, and form an insoluble compound. Such are oxalic, sulphuric, and hydrosulphuric—sulphide of hydrogen—acids, *et cetera.* Even water impregnated with carbonic acid readily causes the carbonate of lead to dissolve; but, in this instance, there is no escape of carbonic acid, but an assimilation of that contained in the water. By the action of heat, as already signified, it is convertible into litharge or minium according to the intensity of the caloric and the duration of its application. Produced according to the above method, it is a compound of one equivalent of oxide of lead and one of carbonic acid; sometimes, however, it is met with as a basic carbonate—that is, a carbonate wherein is contained a proportionate quantity of base without being assimilated with its equivalent amount of carbonic acid. Sometimes when prepared on the large scale by certain processes, more or less acetate or sulphate and oxide of lead are found in it; but their quantity will be proportionate to the purity of the compounds taken, and the care bestowed in the manufacture. It consists of—

	At weight	Centesimally.
1 Eq. of oxide of lead,.....	112	83·59
1 Eq. of carbonic acid.....	22	16·41
	134	100·00

and its chemical symbol is $Pb\ O, CO_2$.

The manufacture of white lead, though of long standing, and comparatively very extensive, has been, till within a few years, very fatal to those engaged in the operations. M. DE RONLZ states that during the eight years ending in 1844, the number of patients admitted to one hospital—the *Hôpital de la Charité*—attacked with *lead colic,* amounted to one thousand one hundred and sixty-three, of which number four hundred and six were persons employed in the manufacture of white lead, and three hundred and eighty-five were painters. It is pleasing to state, however, that endeavors are now generally made by proprietors of white lead factories to remove the causes of the frightful mortality so long produced, by adopting proper machinery for the execution of such parts of the business as prove most dangerous to the health of the workmen, and by enacting rules which enforce the observance of every precaution on the part of the employed.

Carbonate of lead can be prepared in several ways, and of late years various methods have been introduced for its production, all of which may be said to be modifications of two standard processes—namely, the Dutch method, in which the reactions are effected by operating on metallic lead with acetic acid, and decomposing carbonaceous matters at a comparatively elevated temperature, and without any other moisture than steam; and the other, wherein the carbonate is thrown down from a solution of basic acetate of lead by transmitting carbonic acid through it. These modes offer an unequal degree of advantage to the manufacturer; for although the second is the more rational, as will be seen afterwards, yet the salt produced is different in its molecular construction from that obtained by the first method, and on this account does not suit the wants of the painter or color-maker so well. The particles of the precipitated compound are comparatively large, and appear of a semi-transparent crystalline form; whilst the other is amorphous, its formation being effected by the successive decomposition of the smallest possible quantities of the basic acetate. Hence it is more finely divided, and presents a larger number of particles in a given bulk than the white prepared by precipitation. In principle, however, the two methods are the same, since the carbonate is produced in both by the decomposition of a basic acetate of the metal, the excess of the base being removed by the carbonic acid, and leaving a neutral acetate to react further on the metallic plates in one case, and on litharge in the other, so as to reconstitute a basic salt, which, as soon as it is produced, is acted upon as before. In this way the work proceeds; first, a basic salt is formed, and is decomposed, but yields by that reaction a body capable of producing the first substance an indefinite number of times. The nature of these changes will be more easily comprehended from the following equation, which explains them with special reference to the Dutch method:—

$$\underbrace{HO, C_4 H_3 O_3}_{\text{Acetic acid.}} + \underbrace{3 Pb}_{\text{Lead.}} + \underbrace{O_3}_{\text{Oxygen.}}$$
$$= \underbrace{3 Pb O, C_4 H_3 O_3}_{\text{Tribasic acetate of lead.}} + \underbrace{HO}_{\text{Water.}}$$

That is, with one equivalent, or sixty parts by weight of pure acetic acid, three equivalents, or three hundred and twelve parts of lead, and three equivalents, or twenty-four parts of oxygen,—one equivalent of the tribasic acetate is obtained. The second part of the process, so far as its chemical bearing is concerned, may be briefly explained thus:—

$$\underbrace{3 Pb O, C_4 H_3 O_3}_{\text{Tribasic acetate of lead.}} + \underbrace{2 CO_2}_{\text{Carbonic acid.}} = \underbrace{2 Pb O CO_2}_{\text{Carbonate of lead.}}$$
$$+ \underbrace{Pb O, C_4 H_3 O_3}_{\text{Neutral acetate of lead.}}$$

In this decomposition, three hundred and ninety-six parts, or one equivalent, of the basic acetate, is represented to yield two equivalents of its base to the carbonic acid present, thus producing two hundred and sixty-eight parts or two equivalents of carbonate of lead, and leaving the third equivalent of oxide combined with the whole of the acetic acid. The neutral acetate thus produced takes up two equivalents more from the metal unacted upon, and produces another proportionate quantity of basic salt, which undergoes the metamorphoses above represented.

To bring about in the readiest and most inexpensive manner the modifications above shown, is the object to be aimed at in the manufacture, provided the product has that degree of divisibility and opacity which is possessed by that recognized as first quality in color and body.

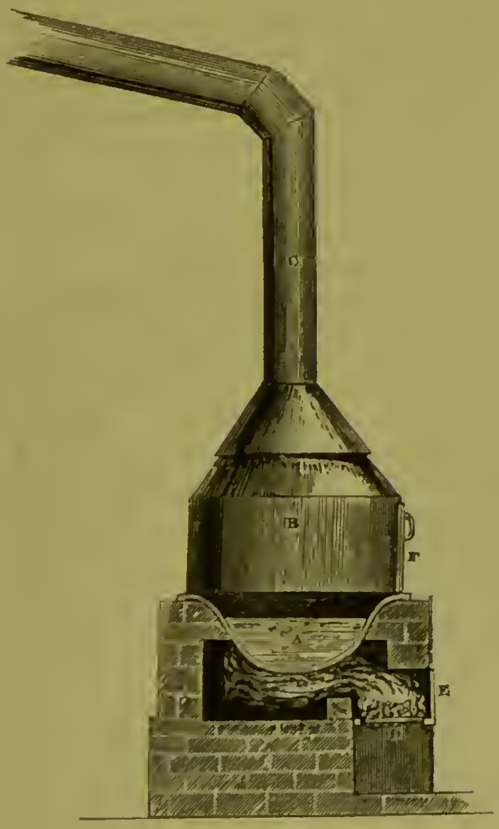
Dutch Method.—The first step in the old Dutch process, consisted in casting the lead into sheets in the following manner: the metal being melted was poured out upon iron plates, and as soon as the surface began to exhibit signs of consolidating, the iron plate was inclined, and the fluid lead allowed to flow back into the pot. The sheet of lead which was thus left was removed, the iron plate cooled in water, and another sheet cast in the same way. In this manner several hundredweights of lead were converted into thin sheets, in twenty-four hours, varying in thickness from one twenty-fourth to one forty-eighth of an inch. The plates so formed were bent in the middle, the bend being occupied by a slip of wood. A number of these was arranged in a wooden box, four and a half to five feet long, twelve to fourteen inches broad, and nine to eleven inches deep; the sheets being so disposed as not to touch one another, nor the sides or bottom of the box. An acid liquor, consisting of four quarts of acetic acid, and four of wine lies, was also put into the same receptacle, and the cover placed securely on. Sometimes the acid mixture was varied according to the ideas of the manufacturer. When a number of these was so prepared, they were introduced into a stove-room, where the heat was sufficiently elevated to cause the evaporation of the acid, so as to bring it into contact with the sheets of lead. The stove-room was of such a capacity as to receive about ninety boxes, and had only one door. A temperature, averaging 86°, was maintained during fifteen days, in which time the plates were acted upon by the acetic acid, and the carbonic acid from the fermentation of the wine lies, assisted by the air and moisture, so that they presented a thickness of a quarter of an inch, whereas, before the operation, they did not possess a twentieth. After this the plates were shaken, in order to detach the crust of white lead, which was subsequently ground and washed. Horse-dung was sometimes employed in this operation, to raise and maintain the temperature by its fermentation, in which case the covers of the boxes were secured by pasting paper round their edges, in order to guard against the discoloration of the white carbonate by the sulphide of hydrogen given off during the decomposition of the dung.

Such is an outline of the old process pursued in this manufacture; but for many years it has been conducted on a more extensive and simpler plan, which was first adopted by the Dutch themselves, and from them has been borrowed by the French and English. On this improved system, the work, instead of being performed in boxes, is executed in large rectangular spaces, inclosed by stout walls constructed of bricks or masonry, within which pots of acid, containing coils of sheet lead, are piled in *stacks*.

The several stages in the manufacture of white lead, by the new Dutch process, may be divided into the casting of the metal, the erection of the beds, or *heights*, in the *stack*, the taking down of the same, the screening or unsealing of the crusted lead, the grinding of the scales, the grinding of the white lead in water, the exsiccation, the grinding of the white dried loaves, alone or with oil, and the packing.

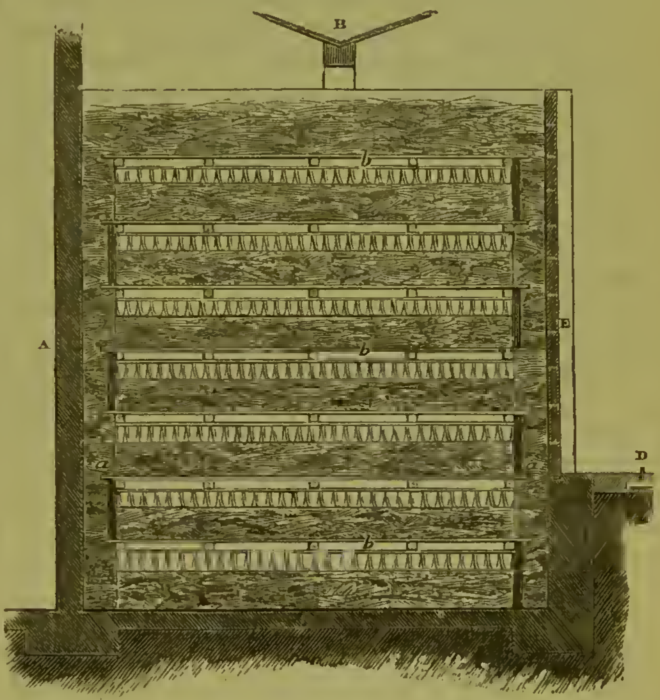
Casting the Metal.—A quantity of metal, of that quality which is deemed the best for the production of white lead, is put into a cast-iron boiler or pot, and melted; this boiler is very often exposed in the foundry, yet the method of inclosing it in a hood is to be preferred; for then, not only are the workmen protected from any fumes which may arise from the melted bath, but from spirtings which follow the accidental introduction of moist lead from the screening or unsealing apparatus. Fig. 335 is a vertical sectional view of this pot, showing the position of the hood used as a protection to it. In this figure, A is the pot wherein the lead is melted, and which is surmounted by the hood, B, in connection with the chimney by the tube, C. D represents the fire, E the fire-door, and F an aperture in the hood, which can be closed at pleasure, by a double sheet moving in grooves at either side. These plates are slid backwards, when the metal, which should be only a few degrees above the melting point, is to be drawn out in ladles to be cast in the ingot plate moulds. Thin plates, from sixteen to twenty-four inches long, four wide, and from two-fifths to one inch in thickness, are thus formed, which are afterwards rolled into a coil, to be introduced into the pots, where they are exposed to the chemical effects of the acids and air in the subsequent part of the business. These pots have in the interior a ledge, *a*, whereon the coiled plate is supported, when they are charged in the stack. Latterly many manufacturers, and especially the English, employ the lead in the form of *grates* or *crates*, as it presents a greater surface, and permits a freer circulation than the former. They are formed by casting the lead on an iron slab, grooved by parallel, longitudinal, and transverse gutters, an inch apart, into which the fluid metal runs.

Fig. 335.



Construction of the Stacks.—The arrangement of the *stacks*, or dung-pits, is represented in Fig. 336, which is a vertical section, filled with the several layers of dung, acid pots, lead plates, and boards successively. A represents the wall, and B the roofing which inclose these spaces. A corridor runs along the sides, in which is a railway, D, for transporting the waggons of dung, boards, *et cetera*, to the space where required. In the front of each of these a door, E, rises the whole height of the stack, to facilitate the introduction of the materials, but which is closed by boards placed crosswise as the several beds are erected. The dimensions of these stacking-spaces vary in different factories, it being supposed by some parties, that the conversion succeeds best in large stacks, whilst others maintain that stacks of lesser dimensions afford better results; and, for reasons which will be presently adduced, doubtless stacks of a medium size operate best. The dimensions usually given average from thirteen to sixteen and a half feet in length, thirteen to fifteen wide, and about twenty high; and in extensive factories such a number are constructed as will permit the gang of workmen to erect and dismantle one daily, the others being in a proportionate stage of advancement as they are being approached. In this particular part of the manufacture very little improvement has been effected on the method adopted years ago.

Fig 336.



These spaces are filled up with material, by a gang of workmen, who are generally paid a definite sum for the erection of the stack. A bank of dung which has been used previously, is raised round the walls of the pit, a foot in breadth, and of the height of sixteen to eighteen inches; in the space thus inclosed, fresh horse-dung to the depth of sixteen inches is spread. A layer of pots, eight inches high, and nine and a half diameter at the top, are placed side by side, till the whole space with the exception of the dimensions of the first embankment, *a*, is covered. Each of these pots, which are glazed in the interior, is charged with a gill and a half, or from that to two gills of common acetic acid, and a roll of sheet-lead; excepting a few which are placed towards the middle and at the corners, that are three quarters filled with vinegar. Ten to twelve hundred of these pots are placed in one floor, or *height*. After arranging the pots and supplying them with the necessary quantity of acid, and resting a spiral of lead on the interior ledge of each pot, another bed is formed, composed of triple or quadruple sheets of lead, laid horizontally upon the first, till the whole surface is covered. Planks, or stout boards, are now laid on the latter, and upon these another layer of lighter boards is placed, as seen at *b b* in the foregoing figures. A second bank of old dung is then formed round by the walls, and a new bed of dung spread as described, upon which a second layer of pots is deposited, and charged with acid and lead, in the same way as the last. This process is repeated, alternating the dung, the pots, lead sheets, and boards, till the pit is filled; only that the layers of dung are only twelve inches thick, from the first till the top covering, which is made with old dung, and of a thickness of twenty to twenty-four inches. Eight heights or layers of pots usually constitute the stack, but sometimes ten are introduced. At either end of the several beds, alternately, a space is left vacant, for instituting a draught from one bed to another, and increasing, at the same time that it equalizes, the effect. Every stack when completed contains for each bed or height, together with the boards, dung, and pots, about seven gallons of vinegar, or fifty-three in the entire stock of eight beds, and from one ton four hundreds to a ton and a half of lead, making from nine and a half to twelve tons of metal in the whole. Four men can lay two heights in a day, so that in four days they can complete a stack. In many establishments, gas is especially manufactured for lighting the premises, so that in winter the operations can be carried on with artificial light.

A period, varying from five to six weeks, is allowed for the conversion of the lead into carbonate to the fullest extent.

Although in those establishments where horse-dung is employed, it is reported that the health of the workmen does not suffer in consequence of the offensive smell which is evolved from these masses of decomposing matters, still the method adopted in England of using spent tanners' bark instead, is much more agreeable; and although in its operations it is slower than the former, the product is not liable to be darkened by sulphide of hydrogen, which the dung evolves during the decomposition of its sulphur compounds. When tan waste is used, nine or ten weeks are required to carbonate the metal. Whilst the materials remain, the several layers of dung or tan enter into a fermentation, which determines a rise of temperature sufficient to determine the evaporation of the acetic acid and water from the pots; and these vapors, coming in contact with the metal in the presence of the oxygen of the atmosphere, effect its oxidation, and the formation of an acetate of lead, in which there is an excess of base. Carbonic acid is likewise evolved from the eremacausis of the organic substance, which decomposes the film of basic acetate, setting free a neutral salt to take up fresh quantities of the oxide of the metal, which is likewise broken up as before. In this way, the production of carbonate of lead proceeds in exceeding small portions; but the operation being continued for a length of time uninterruptedly, and a vast area of lead being operated upon, a considerable quantity is produced.

It is the minute state of division of the carbonate, arising from its slow and gradual production in small portions, which distinguishes the white lead produced in this way from the same compound when it is obtained by precipitation from the solution of the basic acetate; for in the latter case the particles are larger and semi-crystalline, and, when used with the brush, the white lead fails to cover the same space with a coat of opaque paint, as will an equal weight of the carbonate obtained by the Dutch method. This opacity and extreme division constitute what in the language of the trade is termed *body;* and notwithstanding that other modes of preparation, more desirable in a sanitary point of view than the one under consideration, have been suggested, yet the want of this body in the manufactured article condemns it in the painter's estimation.

A great drawback upon the Dutch method of operation is the irregular manner in which it proceeds; for sometimes the temperature in the centre of the stack is as high as 194° and even 212°, which causes the rapid evaporation of the acetic acid, and, the circulation of air being imperfect, a corresponding corrosion is not produced; on the other hand, the portion towards the walls often does not acquire sufficient heat to evaporate the acid, and, therefore, the production of carbonate is not as great here as might be expected. The best results are obtained when there is a due degree of circulation of air, and a temperature of from 100° to 120° is sustained.

Unscaling.—When the time necessary for conversion of the lead into carbonate has elapsed, the dismantling of the stack is begun. The superior layer of material is thoroughly removed, and afterwards the plates of carbonate of lead are exposed by taking off the boards and planks which had protected them. This being done, the carbonated plates and spirals in the pots are taken and deposited in small wooden boxes, in which they are carried to the part of the factory where the unscaling or screening is proceeded with. In the old system this part of the work proved eminently unhealthy; for the method pursued was calculated to load the atmosphere with a great deal of impalpable powder, which, being inhaled, poisoned the operatives. The plates were taken up with the naked hands, and the crust of carbonate detached by striking them against one another; the larger part was thus removed, but a considerable quantity still adhered, and to detach it a number of the plates was laid over one another on a thick flag-stone and struck with a heavy mallet. Here the greatest danger was risked; for by the hammering of the plates, the surrounding air was loaded with the dust, which was productive of a double injury—that of a loss in the product, and of danger to the health of the workmen. Fortunately for the sake of humanity, science has come to its aid; and now, excepting in some isolated cases, the stripping of the plates is performed by machinery, which is so inclosed that no appreciable escape of the white lead takes place, and the air in the room remains pure and wholesome. At the establishment of M. LEFEVRE of Lille, in France, the following is the method adopted:—The men who take the sheets from the pots are protected by large lamb-skin gloves, in order that none of the lead may come into contact with the skin, and consequently they are not endangered, as no absorption can take place. The plates are brought in a small truck to the base of the machine, and lifted by means of an endless rope to which a bucket is attached, to a table, where the unrolled sheets which were in the pots, as also those resting upon them, are laid on an endless piece of leather, which carries them forward to a series of grooved rollers, between which they pass. The rollers reduce the matter to such a degree of division as to prepare it for the grinding-mills to which it is afterwards subjected. For this purpose it is first moistened, and then carried to the grinding-room, where it is passed under a number of horizontal millstones. Here it is ground and forced out into baskets by the centrifugal motion of the stones, through a sluice at opposite sides of the mill. From the baskets the fine paste is put into pots, and placed in the drying-house, where it remains for ten or twelve days.

The drying-house is a square apartment with solidly built walls, and furnished with shelves at particular distances; these are constructed of stout iron bars stretched longitudinally by the walls, and strengthened by uprights of the same metal. In winter, the apartment is heated by a fire of pit coal, surmounted by a huge canopy of cast-iron from which the caloric radiates to all parts of the room, thus raising the temperature of the air, and causing the expulsion of the water from the salt. In summer, the circulation of a current of air is sufficient to effect the desiccation, so that the mass of white lead contracts considerably, and also acquires such hardness as will resist handling. The loaves thus assume the form of the moulds, and as many of them as remain whole are taken out of these vessels, by inverting them on trays, which are afterwards deposited on shelves in another apartment, into which heated air is forced. Here a further quantity of moisture is expelled. Finally, the loaves are wrapped in blue paper, and put up in barrels for the market. The broken loaves are carried to a mill, where they are ground to powder, and packed in barrels, or made into paint by mixing with the ground white lead from eight to ten per cent. of oil.

Until these improved methods were introduced, the reduction of the white-lead to an impalpable powder presented the gravest disadvantages, besides being positively destructive to the health of the workmen. The grinding was generally effected under revolving head-stones, upon a cast-iron basin of the ordinary shape, the coarse material being introduced and withdrawn with the spade; and during this necessarily slow procedure, the dust arising from the agitation of the substance and its removal from one place to another, in the exposed manner in which it was done, had a rapid and injurious effect. It is the Editor's belief, that in most establishments of any repute, all these operations are now performed by machinery, and that to arrest any dust, water is employed where the various departments are not isolated from the remaining space.

The pulverization of the imperfect moulds is effected, in the factory already alluded to, by means of horizontal marble mills, enclosed by a metallic covering which is securely fixed in its place, so that any of the carbonate which might otherwise pass into the surrounding air is completely arrested.

Latterly, the French and Dutch manufacturers are adopting the English custom of compounding the white-lead with oil at once, and thereby preventing two grave inconveniences; for not only does the preparing of it in loaves and powder offer greater trouble to the manufacturer, but it is fraught with danger to the color-maker and painter, because rarely have the latter such arrangements as to effect the mixing without exposing the operator to the danger of inhaling the poison, and thus laying the foundation for lead or *painters' colic.* Till within the last few years they were generally compelled to perform this operation, and the frequent cases of lead poisoning gave rise to the popular term, by which the disease was recognized among this class of men. This danger is obviated now-a-days by converting the white lead into paint in the manufactories; it is done expeditiously and without risk in an apparatus entitled a *kneader*, somewhat like that used in large baking establishments. This is a cylinder, in which a square iron bar, furnished with arms, is fixed longitudinally. The latter is turned by means of a strap passing over a drum, and another in connection with the engine shaft. All the materials—white lead, and oil to the extent of eight per cent. of the lead compound—are introduced by the doors, which are firmly closed, when the machine is at work, by a lever, secured by a bolt. When the two are mixed the paste is drawn out, and if necessary passed through a grinding mill to render it more homogeneous.

Such is the general character of the arrangements in the well regulated factory of M. LEFEVRE of Lille. Here there is a large saloon at the disposal of the men, where they put on and divest themselves of their factory dresses, and perform their ablutions; and another which is used as a refectory, into which they are forbidden to enter in their ordinary working coverings. Gloves made of lambskin are supplied by the proprietor, and worn by all those who are exposed to handle or touch the white lead, so that the danger of absorbing any portion of the poison through the pores of the skin is avoided. All these precautions are not without their merited return, since it is a rare thing, even in the course of several years, to hear of any ailment among the operatives brought about by the nature of their work.

On a par with the foregoing for the general arrangement, and the healthy atmosphere pervading it, is the factory of Messrs. WALKER, PARKER, and Company, previously mentioned. Here the arrangements for melting and casting the lead in crates are similar to those already described. The acetic acid is prepared on the premises. The stacks, also, of which there are thirty-four, are similarly constructed, only that the source of the carbonic acid and heat is tan, instead of the dung used by the Dutch and French manufacturers. It is usual to construct the beds of the several materials in the ordinary way, only that the layer of tan is somewhat thicker than if it were horse-dung. Another difference in laying down the bed of pots, with the exception of about two hundred to two hundred and fifty, is, that the lead is laid flat upon their mouths, in a layer of four, five, or six crates, each weighing about three pounds avoirdupois. The pots, therefore, are simple internally-glazed vases, capable of holding a quart or thereabout, with the exception of the two hundred and fifty above alluded to; these have a ledge in their middle, upon which a coil of the crate lead rests, and are arranged round the circumference of the floor, and at intervals in the middle, for the purpose of supporting the planks, boards, and other overlaying materials. Acetic acid prepared from wood, and diluted so as to mark 1° on the acetometer, is poured into the pots, to the extent of about half a pint, excepting the larger pots which receive double the quantity. Proceeding thus with each layer, the stack is completed, and is left so for a period of eight or ten weeks. And here, it may be remarked, that the experience of the proprietors of the above works has proved to them, that with an acid marking 1·5°, or over, on the acetometer, the conversion of the lead into carbonate never proceeds satisfactorily, nor is the quantity nearly so large as when a weaker acid is employed; for in the former case too much neutral acetate of lead is formed, probably owing to the generation of carbonic acid and the circulation of air being imperfect, and partly passes off in the waters used in the preparation of the white lead afterwards.

In this mode of manufacture, no danger exists of the white lead being blackened with sulphide of hydrogen, but the greatest care must be taken to have the covering of each layer of pots perfect, lest some of the tan might fall through, in which case it cannot fail to produce a stain. Again, when the carbonisation is imperfect, the carbonate which is produced is of inferior quality, since it is largely mixed with a *sub*oxide of lead, forming a bluish-grey coating on the unattacked metal. The only security against imperfect working in the stacks, is to employ a properly-diluted acid, to select a good quality of tan, and to effect a proper circulation of the air, since with bad tan, there is not sufficient fermentation to generate either carbonic acid, or heat to evaporate the acetic acid; and without the air to oxidise the metal, the repeated action of a small quantity of acetic acid, in producing a large amount of oxide of lead, is impeded. After the carbonisation of the lead, the several layers of tan, wood, *et cetera*, are removed, when the pots will be found emptied of their contents, and the layers of crate lead swelled to double or treble their original thickness, owing to the formation of the carbonate of lead upon them.

The sheets are taken off, put into a small carriage, and conveyed on a tramway to the departments of the work where the parting of the salt of lead from the unoxidised portions of the metal takes place. Since the latter is the highest part of the machinery in the area where the cleansing, grinding, and other operations are effected, the railway mentioned is on the second story of the establishment.

Although in the works of Messrs. WALKER and PARKER, the hermetical sealing up of machinery is entirely dispensed with except in one particular, still rarely is there seen an operation, which in itself is very dangerous, rendered so innocuous with such simple contrivances, as that of the preparation of white lead at the manufacture referred to. Here water is to be found almost in all parts of the factory where the parting and grinding is proceeding, and it serves most effectually to suppress the evolution of the minutest trace of white lead into the atmosphere.

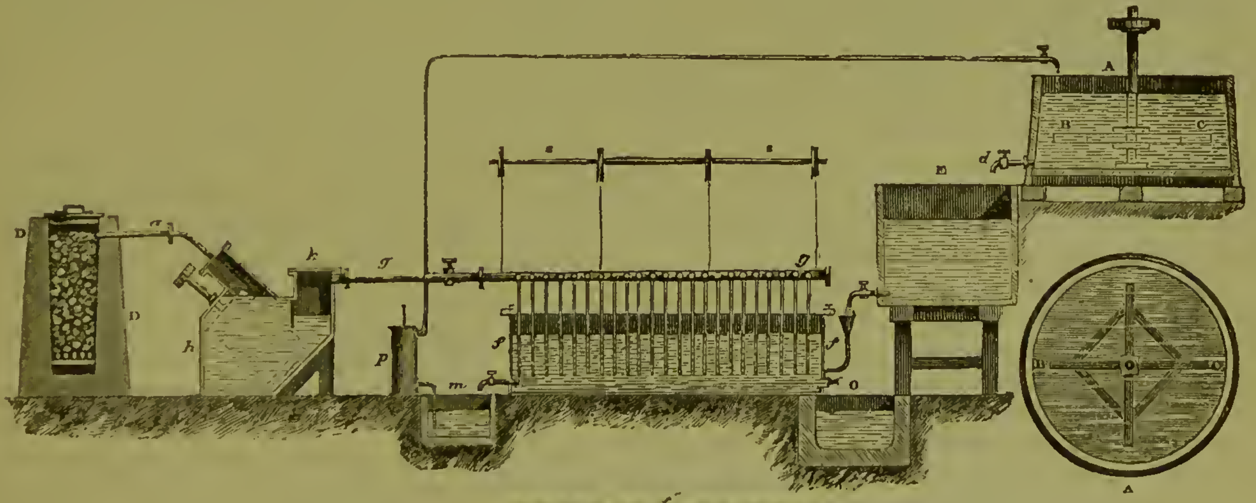
The carriage loaded with the carbonated crates, is, when it reaches the working gallery, emptied into a hopper capable of being covered. This is surmounted by a water-pipe, terminating in a rose, which showers this liquid upon the lead. By the aid of fluted rollers, the crust of white lead is in a great measure detached from the metal, and both are delivered on the end of a rectangular ledge or trough, having a perforated zinc covering above its real bottom. On this there is always retained a quantity of water, and as the material is delivered from the rollers in the drum adjoining the hopper, a man with a small rake moves it back and forth on this with a view of detaching the crust, that was loosened and partly separated in passing between the rollers; the residuary lead still retaining some portions of white lead, is passed between another pair of channeled rollers, and falls upon another table like the preceding, where, by agitating with rakes on the perforated bottom of the trough, and the use of the water, the particles of lead remaining are thoroughly cleaned and removed to a receptacle, whence they are conveyed to the melting house and there recast into crates or pigs of *blue lead*. Whilst on the perforated troughs, the particles of white lead are assorted, and any metal as well as colored parts removed from that which is purely white. For this purpose considerable agitation and working with the rakes is necessary, but still as there is a sufficiency of water, there is not the least escape of carbonate of lead.

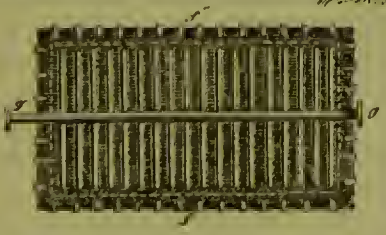
From these troughs the partly-drained salt is conveyed to the hoppers of a number of adjacent millstones, where it is abraded and given out from the sluice in a pasty state; these sluices deliver it into the boxes of other heavier mills placed below the former in a second tier. Finally, the white lead, thus reduced, passes through a third mill, and thence into a deep tub or vat, which also receives a stream of water from the pump; and by means of a rotating agitator the lead is so mixed with the water, that it is carried off in the sluice which forms the outlet to the last vessel, to a series of large tanks or settlers, where the lead after a while precipitates to the bottom and leaves the supernatant water clear. After settling, the bright liquor is siphoned off into a sluice, which conducts it to a well, whence it is pumped up into the higher benches by a forced pump. In this way, the same water is available for a number of times, and each time it becomes purer and less liable to deteriorate the carbonate. The deposited white lead is then taken out with a ladle and put into flat-bottomed dishes, which are conveyed to the drying-house by the younger hands in the establishment. This is a room furnished with shelves of strong iron bars, well-supported all along the four walls; having a large iron casting in the centre, and which is heated by a fire placed outside the building. By the heat radiated from this casting, the temperature of the apartment is considerably elevated, and the moist white lead is dried in the course of a few days. It then appears as a pure white amorphous cake. To convert these into paint they are conveyed to a mill, and the powder passed through a bolter of the usual formation. Oil is next mixed with the ground white lead in a mechanical kneading-trough, and the paste ultimately passed through a mill, and the product packed into barrels for the painter. The mills for grinding the dried product, as well as the sifter, are secured by an envelope which permits no escape of dust; the kneader likewise is securely closed, and the paint-mill like all the others, is almost enveloped in a box, which does not allow any of the matter to escape.

CLICHY WHITE.—Several years ago, THENARD established the principle, that when a neutral solution of a soluble salt of lead is put in contact with an excess of litharge, or oxide of lead, a basic salt is formed, which yields a part of its oxide to carbonic acid, the remaining portion forming a neutral salt with the acid. M. ROARD established a manufactory of white lead in which this principle was carried out by dissolving the litharge in acetic acid, obtained by the distillation of wood or vinegar, in order to produce the basic acetate $3\,\mathrm{Pb\,O}$—a solution of 29° Twaddell, specific gravity 1·145—through which carbonic acid, obtained from the combustion of charcoal, coke, or limestone, was passed, with the view of throwing down two equivalents of the metallic oxide in the state of carbonate, and of leaving a neutral acetate of lead in the solution, ready to operate upon a fresh quantity of the litharge, and convert it into the basic salt mentioned.

The arrangements by which this process is carried on are seen in Fig. 337. A indicates a large tub, capable of holding four thousand four hundred gallons of liquid, in which the acetic acid is made to combine with the litharge, having an agitator, C B. When the solution attains a gravity of 29° Twaddell, it is drawn into the settling vessel, E, by the stopcock, *d*. The vessel, E, which is constructed of copper plates riveted together, and has a capacity of four thousand two hundred gallons, is intended to intercept any particles of lead, iron, or chloride of silver, which might exist in the menstruum, and be carried over in suspension from A. From E the clear liquor is drawn into the decomposing vessel, *f f*, which is about twenty feet long, half this in breadth, and two feet in depth; it is replenished to the height of twenty inches, and holds about two thousand gallons. It is secured with a cover by clasps to the flanges of the side plates, as shown in the drawing. This cover is traversed by eight hundred pipes, which plunge to the depth of thirteen inches into the solution, the other ends being soldered to twenty branching pipes, which extend at right angles from a main, *g g*, at each side; the latter is connected with the blowing apparatus, *k k*, which is supplied with carbonic acid by the furnace, charged either with coke or some other matter for generating the gas. The carbonic acid was at first obtained from the combustion of charcoal; but at the suggestion of DUMAS, chalk and coke in the ratio of two and a half of the former, to one of the latter, was adopted with advantage. A small lime-kiln, D D, is used to burn this mixture, and the carbonic acid is drawn over through the pipe, *a*.

Fig. 337.





After the precipitation of the carbonate of lead, which generally requires twelve or fourteen hours, the contents of the tank are allowed to settle, and after this the solution of neutral acetate is drawn off into the tank, *m*, and is hence transported by a force-pump, *p*, and a pipe, *n n*, to the tub, A, where it recombines with as much oxide of lead as it lost during the precipitation. In this way the neutral solution drawn off from *f f*, and which is found reduced from 29° to 7° Twaddell, can be made to circulate for an indefinite number of times, and be made the agent for the solution of the litharge, so as to bring it into a fit state for its conversion into carbonate by the carbonic acid. There is, however, a slight loss of neutral acetate each time owing to its being partly retained by the carbonate, and partly passing off in the washings, so that it is necessary in practice to renew the strengths of the solutions by the addition of a little acetic acid in the tun, A.

The deposited carbonate is removed after raising the cover by means of cords attached to the main pipe, *g g*, and pullies on the beam, *s s*, the clasps which secured it being unfastened; the white lead is brushed out through an opening, which is stopped at all other times by a plug, into the reservoir, O, where it is washed three times repeatedly by agitation with water and subsidence. The first washings are pumped into the dissolving tun, A. In this way the process is continued almost without interruption, excepting whilst the carbonate is depositing in *f f*, and during its discharge into the tank, O. After the washing, the product is dried and treated in all respects like that obtained by the Dutch process.

It has been suggested to dispense with the mechanical agitators employed in the dissolving tun above described, by substituting cylinders in which the litharge should be inclosed, and to allow the solution of neutral acetate to percolate them, almost in the same way that syrup is made to pass through the filters in sugar-refining.

PATENT PROCESSES.—Various patents have been obtained in England for the manufacture of white lead, mostly on the principle of THENARD.

One of these, taken out by Messrs. GOSSAGE and BENSON, was put in practice at West Bromwich, near Birmingham. In the establishment constructed for the occasion, the work of conversion was carried on in a large longitudinal trough, by mixing a small quantity of a neutral acetate of lead solution with moistened litharge by means of a travelling wheel, and, at the same time, transmitting heated carbonic acid over the mixture. The carbonic acid was in this case obtained from coke, and the white lead, when fully carbonated in the trough, was edulcorated, ground in the usual way, dried, and subsequently mixed with the oil for the purposes of the painter. It is said that forty tons of white lead weekly were manufactured by this method, although for some time the establishment has been discontinued.

Another patent was taken out by Messrs. BUTTON and DYER for a process resembling THENARD'S; only that instead of a neutral acetate of lead being the renewing agent, a neutral nitrate was proposed. Both the neutral solution and the litharge were directed to be mixed and agitated together in a tub, the contents of which were retained at a boiling heat by means of steam passing up through the semifluid mass from a coil of pipe in the bottom. Carbonic acid was also passed into the liquid to decompose the basic nitrate of lead oxide, and precipitate therefrom two equivalents of its base in the form of carbonate of lead. In this, as in the foregoing, the carbonic acid was directed to be obtained from the combustion of coke.

In 1833, a patent was obtained by JEAN BAPTISTE CONSTANTINE TORASSA for the preparation of white lead directly from the metal, simply through the agency of air, water, and carbonic acid. For this purpose the metal was granulated as in the manufacture of shot, and the grains agitated together with water in barrels; the lead dust produced during this abrasion was exposed afterwards to the air for oxidation and carbonisation. This method was tried at Chelsea some years ago by a joint-stock company, who, it is said, expended a hundred thousand pounds in erecting a factory for this process; but it has not answered the expectations entertained of it by the shareholders.

Another patent of a similar nature was taken out by WALKER WOOD in 1834; and in 1847, M. CANNEL specified the following method:—He constructs a hexagonal or octagonal cylinder of lead, six feet and a half long, and fifteen and a half inches or less in diameter. the lead to have a thickness of two to three inches. He incloses this cylinder in a frame made of rod-iron. to one end of which a crank is attached, and places the whole on a stand in such a way as to be readily put in rotation. By means of an opening, or bung-hole, in the middle of the cylinder, the materials, consisting of about two hundredweight of granulated lead and six and a half gallons of water, are introduced. At the other end of the cylinder there is also an orifice in the axis of the cylinder from one inch to an inch and a half in diameter, through which an elastic tube, connected with a bellows or other blowing machine, is passed, till it reaches about the middle of the cylinder.

In the machine thus constructed the materials, as specified above, are put, the bung-hole closed, and the whole rotated at the rate of forty-five or fifty revolutions per minute; this mode of operation is continued during five hours, when two-thirds of the lead will be found abraded to an impalpable powder, but retaining its metallic lustre. On opening the lateral orifice, this fine powder undergoes rapid oxidation, and a hydrate of oxide of lead is obtained. Finally, if the chamber where the blowing apparatus is fixed be charged with carbonic acid from the burning of charcoal, *et cetera*, on putting it in operation, a stream of this gas will be forced into the cylinder, and the oxide of lead will pass to the state of carbonate.

The mixture is then discharged from the cylinder into a tub beneath the lateral opening, and agitated with water, during which the metallic powder falls to the bottom, and the lead salt acquires a remarkable degree of whiteness. As it is somewhat difficult to separate the small metallic portions, M. CANNEL advises to agitate the mixture in a tub having openings at different levels, through which the carbonate may be drawn away. The pasty mass is thrown on cloth filters, and after the water has drained, pressed more or less; then dried in the stove-room and ground with oil in the ordinary way. To facilitate the oxidation in the cylinder, nitric acid may be added to the water to the extent of one and a half to two pounds; or a saturated solution of neutral nitrate of lead may be substituted. The advantages of this method are, according to M. CANNEL, simplicity of operation, a larger product, saving of manual labor, and less chance of loss.

In 1841, Mr. H. L. PATTISON obtained a patent for the manufacture of white lead by means of bicarbonate of magnesia and chloride of lead. The magnesian salt is prepared by calcining coarsely-ground dolomite—magnesian limestone—at a red heat, by which the entire of the carbonate of magnesia is decomposed, whilst the carbonate of lime present is only very slightly affected. This powder is afterwards suspended in water within a cylinder of iron, furnished with an agitating shaft, safety valves, induction and eduction pipes, and carbonic acid is forced into it by a pump as long as absorption of the gas ensues. On drawing off the contents of the cylinder, a solution is obtained marking 5·6° Twaddell, and containing sixteen hundred grains of the carbonated salts per imperial gallon. A saturated solution of chloride of lead in water is now prepared, and which at a temperature of 50° to 60° will indicate a density of 1·008; consisting of one part of the lead salt dissolved in one hundred and twenty-six of water. Both solutions are then mixed together as rapidly as possible, taking the precaution to have the magnesian solution in excess. The quantities of each solution which ought to be taken must be determined by a trial test on the small scale. On running the two liquids in the proper proportions in two converging streams into a tank, from which the mixture issues by a tap-hole at the bottom into a settling vat, carbonate of lead mixed with a little basic chloride of lead, will be found in the latter after subsidence. To separate the chloride of lead which exists in it to the extent of one or two per cent., the dried compound is ground in a horizontal mill with a concentrated solution of potassa or soda, and letting the pasty mass stand for a day or two, after which the chloride of the alkali metal is washed out, and a compound is left, which, when dried and properly prepared, is represented to be equal to the best *ceruse* in body and purity.

Mr. LOTHAM's patent, sealed in the beginning of 1847, directs that a six-feet cubic apartment should be provided, in which by upright posts and horizontal wooden rods, the sheets of lead should be conveniently supported without touching one another; the sheets to be two feet long, one in breadth, and one-sixteenth of of an inch thick. Beneath the floor should be a flue in connection with a furnace, by which the chamber may be heated to a temperature from 72° to 96° Fahr. On the floor is placed a tub in which are eight pecks of malt, two pounds of sugar, six pints of yeast, and twelve gallons of water. This mixture ferments, and ultimately gets mouldy, when it is drawn off into other vessels, in which it is mixed with two gallons of vinegar and heated by steam, after which it is gradually introduced by pipes to the floor of the chamber. It gives off acetic acid, which corrodes the lead, and the carbonic acid from the fermentation converts the oxide into white lead.

TOURMENTIN patented a process in 1847, for manufacturing white lead from the chloride of this metal. The latter compound was to be produced by grinding litharge, chloride of sodium, and water together, employing an excess of the litharge; basic chloride of lead was thus obtained, which, upon treatment with a stream of carbonic acid, yielded a precipitate of carbonate of lead, leaving a neutral chloride of lead in the solution. By drawing off the latter, and boiling it with chalk till, on testing with sulphide of hydrogen, the clear liquid gave no blackening, the portion in the solution was precipitated as carbonate, and afterwards separated from the lime salt by washing.

RICHARDSON prepares white lead by taking the crystals obtained in the desilverizing of ordinary lead by PATTISON's process, or metal otherwise reduced, and mixing with it from one to one and a half per cent. of vinegar, or a proportionate quantity of nitric acid, acetate or nitrate of lead diluted with water; and after turning the mixture over repeatedly, placing from twenty to thirty hundredweight of the mixture upon the shelves of a chamber lined with lead, slate, or stone. Heated air is admitted by a pipe furnished with a stopcock, also steam to retain the compound moist, and carbonic acid from any convenient generator. Provided the temperature be retained at 96°, or thereabouts, the conversion of the lead will be effected in ten days or a fortnight. The salified mass is then removed and ground, then agitated with water, and any metal which separates returned to the chamber with fresh acid.

DISBROW RODGERS in a patent sealed in August, 1849, gives a process which consists in suspending sheets of lead on frames of wood in a steam-heated chamber, and thus exposing them to the joint action of acetic acid, carbonic acid, and steam; the acetic acid being derived from troughs of pyrolygneous acid into which steam pipes pass, or from other sources placed on the floor, and the carbonic acid from fermenting mixtures of yeast, sugar, malt, and water, also contained in troughs placed upon or sunk in the floor. Of course one condition of the success of the operation is, that the chamber be air-tight or nearly so, and a temperature of 80° maintained by the introduction of steam for a short period several times in the day. Every forty-eight hours this compartment must be entered, to renew the fermenting and acid liquors during the time that the process lasts, which is usually twelve days.

In 1853, M. CHENOT laid before the French Academy a process for the manufacture of white lead, which according to that gentleman offers facilities for the production of this article, that render it much more eligible than the established method. It consists essentially in the treatment of lead ores by metallic sponges, whereby a leaden sponge is precipitated, and this is subsequently exposed to the air and moisture, easily oxidises, and becomes converted into white lead. Pure galena, such as is known as *alquifoux*, is the ore employed by him; it is transformed into sulphate of lead by very careful roasting in a reverberatory furnace, the heat and working during the time being so controlled, that the matter does not enter into fusion. When the whole of the lead has thus been converted into sulphate, the product is mixed with iron or zinc sponges in a suitable vessel which contains an acidulous water, and is heated by steam, or some other mode of artificial heating. The whole is thus left during a period extending to ten or fifteen days, with occasional stirring, at the end of which period the lead will be found at the bottom of the vessel, and a solution of the precipitating agent in the form of sulphate.

By decantation the supernatant liquor may be removed, when the residue is treated with a dilute sulphuric acid, to remove any particles of iron or zinc that may be present with the lead; but the solution, so produced, may be employed to moisten the materials of the next precipitation. After this liquor is drawn off, the residue is washed well with water till neither zinc nor iron, which of them soever may be employed, is detected in the washings; after which it is to be laid on trellises, in layers of ·3937 to ·7974 of an inch thick, and moistened. It will be changed in a fortnight or a month to a magnificent ceruse, of a beautiful white and velvety appearance. The lead sponge oxidised at a temperature of 392° gives the same results, and the tones of these compounds are superior to those now made, and are very powerful in their action. M. CHENOT, in the above communication, assures the Academy, that no manufacture can possibly be safer in a sanitary view than that of white lead, according to the foregoing process; that the product is perfect, and exerts a powerful action on fatty bodies, whilst, at the same time, the compounds are obtained with extraordinary simplicity and precision, without the expenditure of manual labor consequent on the other methods.

Theory of the formation of White Lead.—For a long time, although some general opinions were advanced with regard to the formation of white lead in the fermenting stacks, by the agency of acetic acid, air, and carbonic acid; still, till within a recent period, there existed a degree of uncertainty as to what the real changes were, in the minds and writings of scientific men. It has been already stated in general terms, that there is formed in the *stack* a basic acetate of lead which suffers decomposition, from the assimilation of the basic oxide by carbonic acid, leaving a neutral acetate to operate further upon the metal. Recent experiments have shown, however, that the substance produced is also a basic compound of neutral carbonate of lead, with a hydrated oxide of the metal, and the question was suggested —Why does not the carbonic acid present react upon the free oxide of the carbonate, as well as upon that of the basic acetate which is generated? It would seem at first sight that such a result would be the most likely one to be produced, more especially since the basic acetate must necessarily be in contact with the metal, and that the gas must traverse the exterior coating of carbonate to influence it in any way. Knowing that white lead is capable of assimilating a larger percentage of carbonic acid than that which it yields, it is natural to infer, that instead of a basic compound, a neutral one of oxide of lead and carbonic acid should be obtained. Theory in this case would be in direct opposition to practice, and egregiously erroneous also. BARRESWILL has lately shown, however, that when anhydrous neutral carbonate of lead is added to a solution of the basic acetate of this metal. white lead of the composition above stated separates: and hence the first portions of the acetate which are decomposed by the carbonic acid, although such be a neutral carbonate, are thus changed by contact with an excess of the basic acetate into the ordinary white lead. It follows from this, that if there is a deficiency of the basic acetate of lead, the chief part of the corroded metal will be converted into neutral carbonate of lead, and that its qualities as a paint will be materially depreciated on account of the molecular structure of that body. This inference is strengthened by the experience of white lead manufacturers. There is little doubt of this being the true change which occurs; yet URE believed the metamorphosis impossible, from the fact that acetic acid is regarded by him as exercising a more powerful combination than any which carbonic acid is capable of exerting. It should be remembered, however, that in many chemical reactions the existing state of the elements frequently modifies the changes which in other respects they give rise to, more especially when the substances are capable, like lead, of producing compounds, the constituents of which are held together by a very weak affinity; and although carbonic acid alone does not expel acetic acid from its combinations with one equivalent of lead in the presence of water, the heat of the stack may be conducive to cause its expulsion in the presence of carbonic acid. URE assumed, that in the action of the acetic acid upon the lead a sexbasic compound is produced. which undergoes a kind of eremacausis that determines the conversion of the acetic acid into carbonic acid and water, the former of which is proportionate to the quantity of this gas combined with the ordinary white lead.

$$\left.\begin{array}{l}\text{1 Eq. of sex-}\\\text{basic acetate}\\\text{of lead, + 8}\\\text{Eqs. of oxy-}\\\text{gen.}\end{array}\right\}\underbrace{6\,PbO, C_4, H_3, O_3, HO}_{\text{Sexbasic acetate of lead.}} + \underbrace{O_8}_{\text{Oxygen.}} = \underbrace{4\,(PbO, CO_2)\,2\,(PbO, HO)}_{\text{White lead.}} + \underbrace{2\,HO}_{\text{Water.}} = \underbrace{2\,(2\,PbO\,CO_2, PbO, HO)}_{\text{White lead.}} + \underbrace{2\,HO}_{\text{Water.}}$$

No reliable experiments, however, are extant to show whether any such combustion of the acetic acid takes place, or that the sexbasic compound of lead is produced in the stack.

It was also supposed that the oxidation of the metal did not take place through the medium of the oxygen of air, the stack being thought too compact for the due circulation of the volume necessary for this purpose; but rather that the acetic acid was the means of effecting, first the oxidation, and secondly, the carbonization; the extra carbon and hydrogen of the deoxidised acid being evolved as a peculiar etherous combination. It is needless to say that this view was erroneous, for, in the first instance, the quantity of acetic acid employed bears no proportion to what would be necessary were the manufacture to proceed in conformity with these changes; besides, HOCHSTETTER and others have proved, that where atmospheric air is excluded, carbonic and acetic acids are insufficient to convert the metallic lead into the carbonate to the extent which occurs in the system commonly adopted.

Composition of White Lead.—From multiplied analyses, by several well-known chemists, of the English and foreign white lead of various factories, it appears that its composition almost invariably is, two equivalents of the protocarbonate of lead united with one of the hydrated oxide, and agreeing with the formula $2\,(PbO, CO_2)\,PbO, HO$.

MULDER, in his researches upon white lead, arrived at these results; so also did **HOCHSTETTER**; and latterly the examinations of **LINK** and **PHILLIPS** corroborate the same. The precipitated compound, such as that prepared at Clichy, has a similar composition, owing to the fact expressed in the preceding, that by the reaction of carbonic acid or neutral carbonate of lead upon the basic acetate, a precipitate of analogous composition to the above falls. If the transmission of the carbonic acid be continued till the menstruum indicates the evanescent acid reaction peculiar to it, the whole of the lead will be carbonated, and a compound obtained, much less adapted for the painter than if the operation were not pushed so far. Previous to the investigations above alluded to, it was supposed that the Clichy white was a simple carbonate, and that the disparity of effect manifested by it, compared to the Dutch kinds, was owing to this; but **PAYEN** and **URE** proved by strict examinations, that the former variety when obtained in the cold from moderately dilute solutions, was composed of irregular plates finely divided, but the superposition of which did not offer the same degree of opacity as an equal weight of the Dutch white. It would appear, however, that when the compound is thrown down from hot concentrated solutions of the basic salt, the crystalline structure is considerably diminished, and the product is more opaque and spreads better under the brush of the painter.

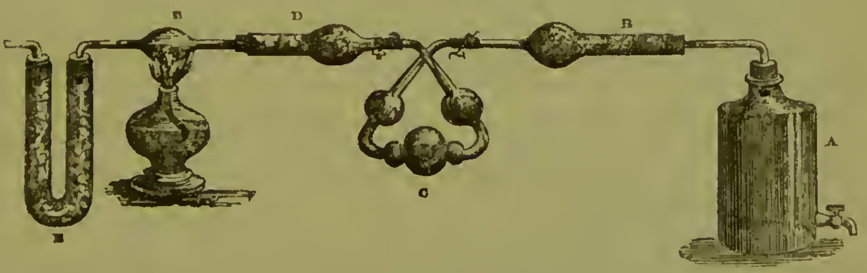
Occasionally a species of white lead is produced by the Dutch method, which yields on analysis numbers corresponding to the formula $3\,(PbO, CO_2)\,PbO, HO$; that is, three equivalents of carbonate to one of oxide of lead. It has a loose friable texture when drawn from the heights, quite distinct from the hard crates of white lead obtained when the metal is almost wholly converted; and is invariably the result of defective corrosion of the metal. This kind of white lead does not cover so well as the hard lead.

ANALYSIS OF WHITE LEAD.—The analysis of white lead as taken from the metal or from the drying-house is very simple, but becomes more difficult in the form of paint, for then not only do the oleaginous matters present inconveniences, but generally speaking various other mixtures, such as sulphate and carbonate of baryta, sulphate of lead, antimonial compounds, *et cetera*, are incorporated. It suffices, when the compound is dry and uncombined with oil, to desiccate a known portion of the average sample, reduced to a fine powder, in a water-bath as long as it ceases to lose weight, and note the loss thus sustained. The crucible may then be exposed to a dull red heat, for the purpose of expelling the carbonic acid; weighing as in determining the water, and when this is done, setting down the loss before heating in the flame, and after. To insure that the whole of the carbonic acid is expelled, two weighings after prolonging the heat should correspond. Pure white lead yields:—

	Centesimally.
Oxide of lead,	86·377
Carbonic acid,	11·310
Water,	2·313
	100·000

Now if the percentage of water and carbonic acid in the sample examined coincide with these numbers, it will be evident that the sample is pure; but should the amount of carbonic acid found be greater than that given, it is a sign the preparation, though not adulterated, is still of inferior quality, since the proportion of the carbonate is increased in relation to the oxide present, and consequently if used as a paint, it loses in body through this constitution. Since a difference of 0·7 per cent. of carbonic over the foregoing numbers in the analysis, indicate that another equivalent of carbonate of lead is associated with the same weight of hydrated oxide, it is evident that the utmost care must be exercised in making a true estimation of the carbonic acid and water. If the latter should not be wholly expelled before experimenting for the carbonic acid, it is plain that an error would be made in the results, since any residuary moisture will be estimated as carbonic acid.

Fig. 338.



PHILLIPS has devised a plan by which all or most of the liabilities to error are obviated; but to manage the operation with success requires some skill and practice. He takes an apparatus fitted up as represented in Fig. 338, in which A is an aspirator connected with the chloride of calcium tube, B; this in turn is joined with the potassa liquor bulbs, C, the second chloride of calcium retainer, D, the tube, E, into which the sample to be analyzed is put, and the U-tube, F, holding, in one limb, pieces of pumice moistened with concentrated sulphuric acid, and in the other, partly fragments of fused chloride of calcium, and solid potassa. All the connections are made by means of corks, quill-tubing, and caoutchouc connectors. About twenty grains of the sample being carefully introduced into the bulb of the tube, E, and united at both ends, the flame of the lamp is cautiously applied to it, and at the same time a gentle stream of air drawn through, by turning the tap of the aspirator. As soon as the moisture is supposed to be expelled, the heat is increased, and the carbonic acid becomes thus liberated, but retained in the bulb apparatus, C. After the carbonic acid ceases to be emitted, and the residue in the bulb presents the well-known appearance of litharge, the parts, B, C, and

D, are quickly detached, and weighed. The acquired weight of B and C, combined, will indicate the carbonic acid in the sample, whilst that of D will show the water present. The oxide of lead is estimated in this way indirectly, since it constitutes the difference. When, however, impurities exist, this will not answer, and therefore, the weight of the impurity must be determined, or that of the oxide of lead combined with carbonic acid, as well as that associated with it as hydrate. If the impurity be of an insoluble nature, such as sulphate of lead or baryta, the carbonate must be dissolved out by acetic acid, the residue washed, dried, ignited, and weighed. Should the insoluble portion be a mixture of the sulphates of lead and baryta, and that the quantities of each are to be found, the most expeditious course is to heat the contents of the crucible with sulphide of potassium or of sodium, keeping the vessel covered. After a quarter of an hour's heating, the flame may be removed, the contents of the vessel washed out with hot water, filtered to remove the excess of alkali, and the residue treated with dilute nitric acid. Sulphide of lead produced in the preceding operation is thus dissolved, and after filtering off the liquid and washing the residue, the metallic oxide may be removed from it in the form of sulphate, by adding sulphuric acid in excess, and diluting. The latter precipitate is then to be filtered, washed with a very attenuated sulphuric acid, dried, ignited, and weighed. If from the entire residue the amount of sulphate of lead obtained in this way is deducted, the difference will be the barytic compound used. When carbonates of baryta or lime are added, these compounds do not part with their acid at the same temperature at which the white lead yields its carbonic acid, so that the estimation of the loss by heat, managed so as to be barely at a dull redness, will represent the proportion of the valuable compound existing in it. The residue may be examined for carbonic acid in WILLS' apparatus, and its amount will give indirectly the weight of carbonate of lime or baryta present in the sample.

ADULTERATIONS.—All the white lead which is manufactured into paint is more or less sophisticated, and chiefly with barytic compounds. The practice is carried on to such an extent, in some cases, that more than three-fourths of the mineral constituents of the paints are adulterants. This is invariably done at the manufactory, and, unless specially required, the white lead is never ground *per se* with the oil; and, therefore, the various qualities of white lead are in some respects synonymous with the extent of spurious matter incorporated with it. In Belgium there are several kinds—the *Kremser white* being unadulterated, but the others largely so: thus, *Venetian white* is a mixture of heavy spar and the subcarbonate of lead, in equal proportions; *Hamburg white*, of two parts of heavy spar and one of the plumbous compound; and that known as *Dutch white* contains three-fourths of sulphate of baryta. Many of these compounds are mixed with a small quantity of charcoal, indigo, or prussian blue, so that the dead yellowish shade which they present may be enlivened to a brighter hue.

Before leaving the subject it may be stated, that of late years efforts are being made to supersede the manufacture of carbonate of lead entirely, by substituting for it other compounds, which, when mixed with oil, give a white paint. Of these, the principal are oxide of zinc, the teroxide of antimony, sulphate of baryta, *et cetera;* but the oxide of zinc comes nearer to the true substitute than the others: for this enters into a combination with the oil, just as the oxide in the white lead gives rise to an oleate that considerably aids in the extension of the paint on the surface, and causes it to form, at the same time, a perfect coating.

Oxychloride of Lead.—This is a compound lately introduced by Mr. PATTISON, who has obtained a patent for its manufacture. It is described as possessing properties which are superior to those of white lead, inasmuch as it does not so readily blacken with sulphide of hydrogen as the latter body. To prepare it, the patentee dissolves pure chloride of lead in water at the temperature of 212°, in quantities averaging five-sixths of a pound to a cubic foot of liquid. Soda, potassa, lime, or baryta in the caustic or hydrated state, may be employed to precipitate the lead from the solution, but as lime is the cheapest, it is of course preferred.

When lime is the precipitant, a saturated solution of it is made in cold water, in which case a cubic foot of the liquid will contain one-half of the equivalent of the lead contained in the plumbous liquor. If the water employed to prepare this liquor contains soluble sulphates or carbonates, a corresponding quantity of the lead will be precipitated in the form of sulphate or carbonate, and consequently more chloride of lead should be employed than above specified, so that the lime may not be present in excess, in which case it would dull the aspect of the preparation. The solutions being thus prepared, they are suddenly mixed, for which purpose the patentee employs two tumbling-boxes of sixteen cubic feet capacity, and placed over a cistern or tank into which the two boxes, when full, are inverted, and cause the two liquids to mix instantaneously. Basic chloride of lead having the composition represented by the equation $Pb\,Cl,\ PbO.\ HO$, that is, an equivalent of chloride and of oxide of lead, falls; and after complete subsidence, the clear supernatant liquor which contains chloride of calcium and a trace of lead, is siphoned off to another tank, and there mixed with a further quantity of lime-water. Should any of the lead salt escape decomposition, it is here converted into the hydrate which falls to the bottom of the tank, and may be recovered. It would appear that when the oxychloride of lead is employed as a paint, the oxide contained in it gives rise to an oleate of lead, and, in consequence of this saponaceous matter, is capable of spreading over an extended surface like ceruse. URE, however, found that water removes the chloride of lead from the paint compounded of this article, and, consequently, that it is not so effectual as the carbonate or white lead.

Physiological Effects of Lead and its Compounds.—With the exception of one or two of the most insoluble compounds of lead, all the others are known to have very active poisonous properties. The sulphide of lead, the sulphate, and sulphite, if possessed of such, are not, however, so virulent as those salts of the metal which are soluble in water, or in dilute acids. It is to be remarked, that miners of galena are seldom, if ever, incapacitated by any derangement to their health arising from saturnine poisoning; when, however, they chance to be removed to the smelting establishments, after a while occasional indications of the physiological effects of lead on the system are observed. Dr. SCOFFERN, when, a few years ago, advocating the use of acetate of lead for the purification of saccharine juices, affirmed the innocuousness of sulphite of lead, owing to its insolubility; but no well-confirmed proofs exist of the truth of the assertion.

Lead, *per se*, is supposed to have no effects on animals; nevertheless its ready solution by the fluids and juices in the stomach, brings it into a state in which it is rapidly absorbed into the system, and thus becomes poisonous. Therapeutically considered, the preparations of lead have sedative and astringent properties, since they diminish the volume and frequency of the pulse, and reduce the secretive functions. Thus, when it is employed for some time, the arteries become reduced in size and activity, as indicated by the smallness and slowness of the pulse; hence its use in checking hæmorrhage, whether natural or artificial, and in reducing the temperature of the body. These characteristic effects extend to the secreting and exhaling vessels, as may be known from the dryness of the mouth and throat, the thirst, *et cetera*, which succeed its absorption. If present in quantities, other very decided indications are observed, such as the well-known leaden discoloration of the gums, of the buccal mucous membrane, and of the teeth; the peculiar taste and odor of the breath; the lead jaundice, and ultimately general emaciation. The coloration of the gums, membrane, and teeth is recognized by a leaden or slate-blue line from one-twentieth to one-sixth of an inch in breadth, which forms on the margin of the gums, nearest to the incisors in either jaw, whilst the rest of the gums appear of a bluish-red tint; the membrane lining, the gums, and cheeks are also of a bluish color, and the lower part or neck of the teeth are stained brownish. It would appear that these various shades of color are occasioned by sulphide of lead, produced doubtless by the traces of sulphocyanogen which is known to exist in the saliva flowing from the glands of the mouth. Saturnine breath is known only to those who are affected by lead through the respiratory organs, such as persons engaged in the manufacture of the compounds of this metal already referred to. Emaciation, which is another of the most marked of the primary effects of lead, shows itself more evidently in the face of the patient, giving to it a careworn, wrinkled, and aged appearance. When the lead accumulates in larger proportions, whether by accident or long-continued use of small quantities of plumbous compounds, it gives rise to various diseases known as *lead colic*, *anthralgia*, *paralysis*, and that which is characterized as *encephalopathy*, and which manifests itself by different morbid phenomena, such as delirium, coma, and convulsions, with or without loss of one or more of the senses. Physicians have observed, that patients are liable to several of these at once, although the most frequent of them is the lead colic.

Lead Colic, the symptoms and characteristics of which need not be entered upon here, is generally accompanied by the blue coloration of the gum, and this enables the practitioner to define the variety of the complaint.

Lead Anthralgy. It shows itself by pains in the limb. These usually become acute by paroxysms, are diminished by pressure, increased by motion, and are accompanied by cramps and hardness of the painful parts. In this case also, the blue line of the gums shows whence the disease springs.

Lead or *Saturnine Paralysis.* This ailment is characterized by the loss of voluntary movement of the parts affected, owing to the want of the power of contracting the muscular fibres of such parts. It is more frequently observed in the upper extremities, although the lower are also liable to be affected by it. The extensor muscles are more frequently diseased than the flexor, so that it manifests itself most frequently in the hands, arms, and legs. Pain is experienced frequently in the affected parts, and sometimes also in the region of the spine. Generally, lead paralysis, succeeds the saturnine colic, although it may come on whilst the patient is suffering from the latter. This disease is likewise distinguished from others of a similar nature, by the blue line in the gums which is very marked at its commencement.

In all these forms of disease as well as the cerebral ailments classed under *saturnine encephalopathy*, it is the general opinion, that the greatest effects are produced from local causes, arising from the inert compounds which the metallic base forms with the albumen, *et cetera*, of the tissues and parts which absorb it. At first sight it would seem, since such a combination is capable of being produced, that absorption could not take place; but though slow in this respect, when compared with other substances, experience has demonstrated its presence in the brain, spinal cord, and other parts of the body, to which access could not be made, excepting from the respiratory organs or the stomach. Some persons are so susceptible to poisoning influences, that the vapor from lead paint even has been stated to enter the system, and produce symptoms of a most alarming character, as recently noticed by Dr. WATSON, the eminent physician of London.

Poisoning by Lead.—When compounds of lead are taken in such quantities as to be destructive to life, the physical indications which are observed differ with the form of combination of the metallic oxide; thus, for instance, the acetate of lead acts as an irritant, but the carbonate—white lead—has no such action, or at best only a very indecisive one; the samo may be observed of the oxide and other compounds of lead, especially those of limited solubility. The general physiological effects already mentioned, are guides which do not fail to point out the cause when death or violent attacks through tho poisonous action of lead follows.

Antidotes.—Two classes of agents are known which lessen or destroy the poisonous effects of lead; these are sulphide of hydrogen and the soluble metallic sulphides, and sulphuric acid and the soluble sulphates. With the first class, black sulphide of lead is immediately formed, and as this body is almost inert, if not innocuous, the further deleterious action of the lead salt is averted, as soon as the metallic base is changed to the form of sulphide. In a similar way the sulphuric acid and the sulphates act, only that a white sulphate of lead is generated in this case. It is doubtful, however, whether the sulphates and sulphuric acid operate as an efficient antidote, since it is probable that portions of this salt are dissolved by the chlorides of the alkali-metals, which are always present in the stomach, and likewise by the alkaline acetate, which is formed when a soluble sulphate is administered in cases of this saturnine poisoning. For the most part the first class antidotes aro applied topically, in the form of a bath, and the second internally, in that of draught, *et cetera;* the former decompose any lead which may be on the skin, and convert it into sulphide, thus preventing its absorption; and the latter check the progress of the poison interiorly.

Acute lead poisonings are rarely observed, excepting they arise from inadvertence or accident, either purely so or malicious; but the first stages of slow poisonings are very frequent, and well known to most of the general medical practitioners in every large town, as well as in the rural districts. The source is almost invariably found to be the water employed for domestic purposes, the lengthened use of which causes a depression of spirits, emaciation, and, finally, colic and paralysis. Several cases of this description have come under the notice of the Editor, wherein whole families were affected, and though the leaden indications in the gums were undiscerned—as their medical attendant in many of them appeared baffled by the continued and frequent complaints—still, carefully conducted analyses proved that lead was the undermining agent. Iron-glazed pipes and pumps, with slate or cemented cisterns, were recommended for adoption, and with a very marked effect, the health of the individuals being completely restored. Many waters containing lead are preserved as by an antidote from effecting any injury to the consumer, and are consequently quite safe for consumption. The substances that react thus are the sulphates, phosphates, and carbonates of the alkalies, and also the sulphates, carbonates, *et cetera*, of the alkaline earths; in fact any neutral salt, the acid of which is capable of combining with lead or its oxide, and of constituting an insoluble compound, has this effect. It is owing to the presence of one or more of these, that mineral or spring water, though passed through lead pipes and retained in cisterns of that metal, remains for tho most part unimpregnated with lead. So small a quantity as three or four grains of a sulphate or a phosphate in a water, prevents after some time the corrosion of the metal; carbonates have a similarly marked effect, more especially the soluble bicarbonate of the alkaline earths, since an oxycarbonate of lead is formed, which is one of the most insoluble combinations of lead, only one part being taken up by four million parts of water. It must, however, be remarked that theso salts do not protect the lead from the solvent action of waters which contain *nitric* or *nitrous* acids in solution. These two acids are products of the decomposition of animal matter, and any water containing them will infallibly act upon lead; and, consequently, it would be highly dangerous to pass such a water through leaden pipes, or to store it in leaden cisterns. All of these insoluble precipitates, after accumulating for some time on the sides of the cistern and on the interior of the pipe, form a solid coating, which in a measure isolates the metal from contact with the water, and, consequently it is protected, and the water remains good and wholesome. Chloride of sodium acts also as an anticorrosive substance to the water, but its effects are less certain than those of the compounds above referred to, since the chloride of lead is much more soluble than either the sulphate, phosphate, carbonate, or similar salts. As it frequently occurs, however, that in spring waters there are appreciable quantities of nitrates, and even free nitrous and nitric acid, as in a water from the private well in the neighborhood of Birkenhead examined by the Editor; the action of such waters upon lead becomes exceedingly marked, and not unfrequently do they give notable indications of lead being in solution after some time, even though they contain sulphates. In these cases the active solvent agent is still left in the water, and continues to act upon the metal, even after the entire sulphuric acid present has combined with the oxide of lead dissolved. Water, therefore, which retains nitric acid either in the free state or combined, whether it be mineral or catchment water, is not so safe for storage in leaden cisterns. In like manner, the water which retains decomposing, organic, nitrogenous matters in solution or suspension, is unsafe so far as regards the action on lead; for as stated above, the transformation of the elements of such by the eremacausis which they undergo, tends to produce, first ammonia, and by a further process of oxidation, nitrous or nitric acid, and at the completion of this change their corrosive action becomes very remarkable—so much so, indeed, as to cause the solution of several grains of lead per gallon. Besides the fact, that waters containing organic decomposing matters are in themselves unhealthy, their subsequent effect upon lead renders them doubly so.

MEDLOCK has latterly patented a method, whereby the nitrates which exert such a powerful action upon lead are removed, together with the organic matter, if the latter be not present in great excess. It consists in suspending coils of iron wire or pieces of sheet-iron in the water, and after a stated period filtering off the deposit which forms. By this means the nitric acid is decomposed by the iron, which is transformed into sesquioxide and falls to the bottom, whilst nitrous gas is set free and oxidizes the carbonaceous matters, which remain still in the fluid so as to yield carbonic acid and a lower oxide of nitrogen.

From experiments made upon some of the water lately supplied to Liverpool, and which proved itself to be a most eligible subject for examination, from the quantity of organic matter, both animal and vegetal, and nitrates, which it contained, the Editor arrived at very satisfactory conclusions, that the object proposed by the patentee may be completely fulfilled.

Action of Water on Lead.—When water which has been purified by distillation from pure caustic potassa, and kept out of contact with tho atmosphere, is poured over clean sheets of lead, and so retained for a considerable period, no solution of the metal will be observed to have taken place, nor will the examination of the water indicate that any of the metal has been taken up. This will not be the case if a comparative experiment be made with rain-water, however carefully collected, even in the open country; for with this the metallic lustre is soon dulled, and a film of carbonate and of oxide of lead forms on the plates, showing that a chemical action must have occurred; and besides, if the liquid is chemically treated, distinct evidence of the presence of lead in solution is found. The same observation will be made with regard to distilled water and lead, when the vessel containing them is exposed to the air, though not to the extent of the former. In these instances, there is a compound of oxide and carbonic acid corresponding to *white* lead, formed through the intervention of the carbonic acid with which the water —in case of rain-water—is charged, or it absorbs this gas in the experiment with distilled water. If the vessel be freely exposed, portions of this carbonate are dissolved; but independently of this, the carbonic acid which is always imbibed from the air, proves much more effectual for its solution, and, therefore, a considerable part will manifest itself to chemical tests, after some lapse of time. Another agent in rain and other waters, that acts with great rapidity on lead, is *nitrous acid;* and latterly Dr. MEDLOCK has shown, that ammonia, by its transformation into this, is capable of ultimately causing the water in which it is present, if retained in contact with lead, to become poisoned. The annexed equation exhibits the interesting transformation:—

$$\underbrace{NH_3}_{\text{Ammonia.}} + \underbrace{6\,O}_{\text{Oxygen.}} = \underbrace{NO_3}_{\text{Nitrous acid.}} + \underbrace{3\,HO}_{\text{Water.}}$$

Of course, some of the nitrous acid will be constantly metamorphosed into nitric acid, oxidation continually going on. This chemist affirms that the nitrate of lead produced in contact with the metal, is speedily transformed into the quadribasic *nitrite,* with evolution of binoxide of nitrogen, which, by combining with another equivalent of oxygen, re-forms nitrous acid. The production of the lead salt is thus explained:—

$$\underbrace{5\,(Pb\,O,\,NO_5)}_{\text{Nitrate of lead.}} + \underbrace{11\,Pb}_{\text{Lead.}} = \underbrace{4\,(4\,Pb\,O,\,NO_3)}_{\text{Quadribasic nitrite of lead.}} + \underbrace{NO_2}_{\text{Binoxide of nitrogen.}}$$

MEDLOCK, *contrary to all preceding views with regard to the action of certain waters on lead,* thus correctly sums up:—

Firstly. The action of any water on lead is entirely due to the presence of *nitrous* and *nitric acid,* resulting primarily from the decomposition of organic matters, and of ammonia contained in the water.

Secondly. Waters deprived of these acids, and of substances capable of producing them, *have no action on lead,* and may be conveyed with perfect safety through leaden pipes, or stored in leaden cisterns. To store or collect water containing a nitrogen acid in cisterns or tanks lined with lead, as is usually done for domestic use, is highly pernicious, since the injuries arising from taking lead into the system, and stated above, may follow. And as no other more convenient means for the storage of water and its conveyance are known, especially in small quantities, the first question relative to the sanitary value of a water which ought to present itself to municipal or corporate bodies, as well as to private individuals, is, does it exert a solvent action upon lead, or does it contain a nitrogenous acid, or any compound likely to produce one. It is true that water which would dissolve this metal in abundance, and, therefore, be rendered unfit for use, is by the presence of certain mineral ingredients rendered less liable to do mischief.

LEATHER.—*Cuir,* French; *leder,* German.—Leather is the compound which the fibrous matter of the skin of warm-blooded animals forms with various substances of an organic and inorganic nature. It remains in a great measure unaltered under the joint influence of air and moisture; and in this behavior differs considerably from the skin, *per se,* since the latter, if subjected to the action of the forementioned bodies, readily undergoes a species of fermentation that resolves itself into the putrefactive kind, and quickly destroys the integument of the skin.

HISTORICAL NOTICE.—Of the early history of leather little is known; still the meagre allusions met with in old records are sufficient to show that it is of high antiquity. Like many other manufacturing arts of long standing, the preparation of leather from the skins of animals originated with the Oriental people, but of the methods adopted nothing is stated to inform the reader of the present day, beyond the remark that alum was used as a tanning agent by the Saracens.

It is recorded that leather was employed among the Romans, long before they acquired the knowledge necessary for its preparation. In those and subsequent epochs it was in request for sandals and other articles appertaining to dress. In the middle ages, it is stated that several uses were made of this article, both personal and domestic, and although the manufacture must have experienced a corresponding impetus, still the mode of tanning or treating skins at that period is in oblivion. According to FOSBROOKE, the Britons in early times exported the skins of their slain animals, but afterwards learned the methods by which they were converted into leather. This is evidenced by the accounts extant of the large tanning establishments which they had, and which were usually erected on the banks of some rivulet, across which they constructed dams for the purpose of intercepting the water for their use, and frequently to the detriment of a large tract of country, which the water occasionally submerged.

Travellers have related that the conversion of the skins of animals into leather is practised by the aborigines of savage nations. Thus, Sir ROBERT SOUTHWELL describes the methods by which the savage tribes of South America prepare skins to make leather:—

On the skin being taken off the animal, the cerebral matter is extracted from the skull, and both it and the skin are dried in the sun's rays. During the exposure, the skin is kept stretched, so that no shrivelling of the hide takes place. When the hunting season terminates, the dried skins are steeped in water, and the hair detached by the use of an old knife; after this, they are placed in an earthen pot with the powdered brains, and afterwards heated to 95°, or thereabouts. By this treatment the cerebrous matter is converted into a kind of soap, which forms a lather with the water remaining in contact with the skins, and it makes the latter very clean and pliable. After remaining immersed for some time, the skins are taken out and stretched in every direction by means of thongs, and a frame formed of upright stakes and cross-pieces. During the exsiccation upon the frame, they are rubbed with a smooth stone, or hard piece of wood, so as to expel the water and fat from the pores of the hide.

Whether the leather employed by the ancient Hebrews and their contemporaries, and of which girdles, *et cetera*, were made, as stated in the book of Kings, was prepared in a similar manner, is unknown. Whatever methods were pursued, it is evident that the making of skins into leather was a business confined to a few who made it their trade, in the beginning of the Christian era, and that the manufacture has been since progressing slowly. Regarding the choice of materials for tanning, such as the barks of trees and the like, it is unknown whether those now in use were then recognized as possessing the virtue of converting skins into leather, or whether the discovery is due to the tanners of the middle ages. It is certain, however, that the scientific principles of the business were not at all, or at best but very imperfectly understood, before the end of the last and beginning of the present century. The investigations of DEYEUX, SEGUIN, MACBRIDE, PROUST, Sir HUMPHREY DAVY, and several other chemists, explained the nature of the changes which took place, and attributed them to true chemical combinations. These researches, therefore, led the tanners to the comprehension of the scientific principles upon which their operations were based, and likewise opened up new sources of improvement. Since then, however, the progress in this art has been much less marked than that of other branches of trade in which chemistry has been a handmaid; and though numerous experiments have been tried, and many patents granted for new processes and improvements, no very decided advantage has been gained to show that the modern system is superior to that practised prior to their introduction. This is the more unaccountable, considering that the growth of social refinements, and increased wants, as likewise the universal impetus which trade, commerce, and manufactures have received during the last half century, created so great a demand for leather as to render it one of the most important articles of manufacture. This is especially the case in England, where—apart from the consumption of this article in boots and shoes—so much of it has been used in connection with machinery, in the manufacture of carding and other apparatus employed in the cotton trade, for saddlery and carriages, in upholstery, bookbinding, and a variety of other branches which are year by year springing up, that the consumption is almost outstripping the production.

M'CULLOCH considers that the leather manufacture ranks third or fourth in importance, being inferior in money value to those of cotton, wool, and iron, whilst others are disposed to think that it is quite as important as cotton. A glance at the extent of this branch of trade will show at once how much it has merited the above rank. M'CULLOCH estimates the number of persons employed in the tanneries alone as exceeding twenty-eight thousand three hundred; and those engaged in the subsidiary trades to which leather gives rise, such as the currier, boot-maker, saddler, *et cetera*, average two hundred and twenty-five thousand, among whom there is expended annually from seven and a half to eight millions sterling in wages alone. The value of the manufactured goods reaches to no less than nineteen or twenty millions annually.

It is plain, however, that without some very great changes or modifications of the old slow process of tanning, the extensive demands for leather, which may be inferred from the preceding, could not have been met. Such modifications have been introduced more especially during the last fifty years, in which time mechanism has done far more than chemistry to expedite the operations and improve the appearance of leather. The mission of chemistry has hitherto extended little further than discovering tanning agents. and extracting the tanning principle, which, when the hide is prepared by mechanical pressure and other treatment, yields up the tannin more readily than the bark. It is nevertheless a fact, that as the operation has been quickened thus far, the quality of the leather has deteriorated proportionably, and hence when a fine kind of leather is required, recourse must be had to the old methods for its preparation.

Proximate Principles of Leather.—As may be inferred from its nature, leather is formed by the combination of the substance of the skin with any other compound which has the property of rendering it imputrescible and elastic. Many substances possessing these properties in relation to skins of animals, are known to exist both in the organic and inorganic classes; but the one most generally employed. as well as the most efficient, is tannin. That a firm chemical union of the two bodies, such as that above referred to, exists, is evidenced by the modified form of the materials, and the physical appearance and chemical behavior of leather, when subjected to microscopical and chemical examinations. The principle in the skin esteemed by the tanner is, as will be shown later on, a gelatino-fibrous compound which constitutes the basis of leather; and the combining agent—tannin—partakes of an acid nature, so that, by uniting with the gelatino-fibrous material, the former is, as it were, thereby salified, so that it is no longer subject to the ready putrefactive change which the skin undergoes under the influence of air and moisture. As the gelatino-fibrous principle forms only one of several others in the hide of the animal, so the tannin or tannic acid constitutes only one among many other substances in the sources whence it is extracted. In order to render the comprehension of the scientific nature of the business of the tanner as easy as possible, it will be necessary to dwell somewhat in detail upon the materials which he employs, so as to exhibit their respective nature, and show how they mutually affect one another. And firstly,—

THE SKIN.—Strictly speaking, the skin of animals is composed of two parts, the *corium* or *cutis*, and the *cuticle* or *epidermis:* the former is the portion which enters into the composition of leather, and forms the true skin, and the latter constitutes the exterior covering in which the fur, wool, or hair of the animal is rooted. Some anatomists, however, distinguish three distinct parts in the skin, namely, the *corium*, the *rete mucosum*, and the *cuticle.* These several parts are illustrated in Figs. 339 and 340, the former showing the position of the hair, and the latter the magnified layers of which the skin is compounded. In both, A represents the epidermis; B, the rete mucosum, in which the roots of the hair are embedded; C, the fibrous tissue of the true skin; and D, the cellular tissue beneath the latter, showing the fat cells, *a*, in Fig. 340, and sweat glands, *b*, with the follicles, *h*, through which this secretion passes out to the surface of the skin.

Fig. 339.

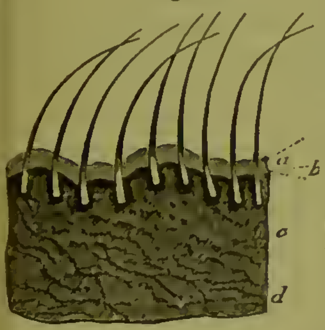
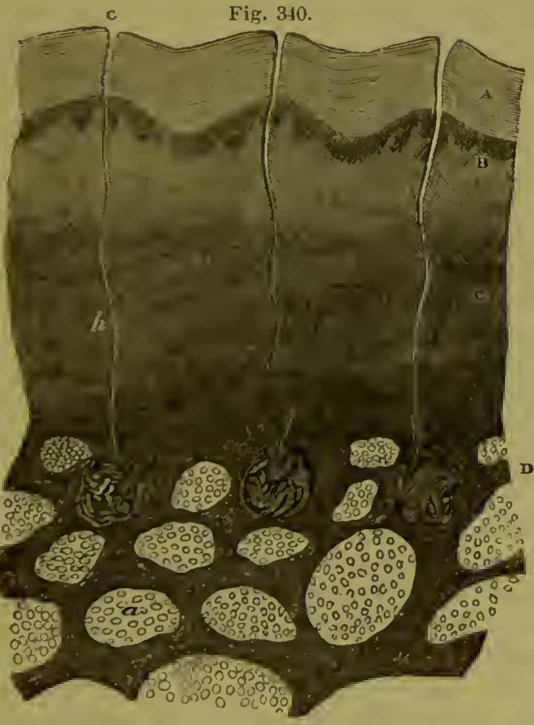


Fig. 340.



Behavior of the Epidermis and Cutis with reagents.—When the fresh skin is immersed and macerated repeatedly in water, the matter of the cuticle is separated from the fibrous substance of the cutis, not by the solution of the former, but, as it would appear, by dissolving an extractive matter amounting, according to Weinholt's analysis, to about eight and a half per cent., and which is probably to some extent intermediate between the horny matter of the cuticle and the cutis; weak acids also abstract it, but solutions of the alkalies and of many of their salts are more effectual for bringing about the separation, since these agents dissolve it. The epidermis, which is analogous to horn, does not combine with tannin or any other substance by the agency of which leather is produced. Hence it becomes useless to the tanner; and therefore, the first process to which hides and skins are subjected by him, is that for removing the hair and epidermis, both being useless.

The corium, deprived of the epidermis, is a substance organized of a number of fibres ramifying and intersecting one another in every position; leaving, however, interstices contracting in size as they reach the outer portion, and which are more or less charged with fluid matter that serves to renew the cuticle and keep the skin pliant and moist. On treating the skin with water these matters are removed, and ultimately there remains but the fibrous portion saturated with water. In this state it appears semitransparent, and, if the water be expelled by a gentle heat, it assumes the physical appearance of horn, constituting only about thirty-two and a half to thirty-three per cent. of the raw hide. From Weinholt's researches, it appears that the skin deprived of the epidermis and its subjacent fluid, as also of the mucous membrane and fat on the interior, affords forty-three per cent. of solid matter, yielding—

	Centesimally.
Fibrous matter,	74·42
Uncoagulated albumen,	3·49
Extractive matter—soluble in water; insoluble in alcohol,	17·44
Extractive matter—soluble in alcohol,	2·32
Fatty matter and loss,	2·33
	100·00

Digestion in water removes the albumen and extractive matter taken up by this menstruum; in alcohol, the further portion of extract dissolves, and ether separates the fat with which the residue is impregnated. If the corium, deprived of the epidermis, be treated with boiling water, it dissolves, with the exception of a little fat and some nervous filaments; and when the liquid is evaporated slowly, a gelatinous residue is left, which, when the entire skin is operated upon, forms the glue of commerce.—See Glue, *ante*, Vol. II., page 181.—This effect of the water does not arise, however, from the solution of the gelatin which, as might be supposed, the skin contains, but it modifies the components of the fibrous tissue so as to bring them into this compound. The same property is possessed by acids and alkalies in a more powerful degree, since the change is effected by these agents at the ordinary temperature.

Fibrin, albumen, and their modification, gluten, behave in a remarkable manner towards tannin or tannic acid, and by the transformation of the fibrous matter of the corium during the operations to which the skins are subjected in the tanning into a semi-gelatinous mass, they conjointly produce leather.

Tanning Materials.—The second principal component of leather, such as that manufactured into boots and shoes, *et cetera*, is *tannin* or *tannic acid*, a substance of vegetal origin, and very extensively disseminated in plants and trees. For a long time the agent which gave such virtues to oak bark, in converting prepared skins into leather, was little known, and, consequently, the peculiar relation of the proximate principles of this article could not be understood, notwithstanding that, in the absence of this knowledge, the leather manufactured was sometimes of prime quality. Lewis was the first who drew attention scientifically to the subject. He observed, during an investigation of the nut-galls, that they contained a substance which gave a black compound with a sesquisalt of iron and precipitated isinglass. DEYEUX, who also studied the point, noticed this substance, but considered it a peculiar resinous matter. It was not, however, till SEGUIN published the results of his labors, that any definite account of it was given. This chemist showed that the unknown body differed from the acid of galls—gallic acid; that it combined with animal matters, more particularly albumen and gelatin, and formed with them unalterable bodies, the analogues of which constituted the main bulk of leather. Since then, manufacturers have given great attention to this principle in the tanning material, and the consequences are that a greater variety of substances producing tannin, available for making leather, have been discovered, and that considerable expedition in the process has been attained. Although the forementioned chemists, with DAVY, CHEVREUL, PELLETIER, LEGRANGE, GUILLOT, HATCHETT, TROMSDORFF, RICHTER, and PROUST, may be justly said to have given a scientific exposition of tannic acid and its behavior, and likewise pointed out its quantity in those plants that yield it most abundantly—still several more recent investigators have contributed to the stock of information on this subject. According to WAHNLENBERG, tannin exists only in perennial plants, and almost solely in the permanent parts. For example:—1. In the perennial roots of certain annual plants, as the septfoil and bistort or snakeweed. 2. In the bark of the trunks and roots of nearly all perennial trees, especially in the true cortical portion. 3. In the trunk and sap of many trees. 4. In the leaves of perennial plants—in small quantities. 5. In the leaves of different varieties of oak; of the *rhus coriaria*—sumac; of the *arbutus uva ursi*—bearberry; of the *arbutus unedo*—strawberry, *et cetera*, in large proportions. 6. In the capsule of the unripe fruit of the *quercus suber ægilops*—valonia oak; *juglans regia*—walnut; *æsculus hippocastranus*—horse-chestnut; and *terminalia chebula*. 7. In the pulp of the fruit of the *punica granatum*—pomegranate; *rosa pimpinellifolia; garcinia mangostana*—mangosteen; and in the different species of anona.

Of the principal tanning materials imported into England, the following table exhibits the names, although a considerable quantity of oak bark—*quercus pedunculata*—is obtained in this country:—

Common title.	Botanical name.	Whence imported.
Oak bark, ...	Quercus pedunculata,..	Flanders, *et cetera*.
Larch bark,....	Pinus larix,..........	Scotland.
Mimosa bark,..	Acacia sp.,..........	New South Wales.
Babool bark, ..	Acacia arabica,......	Bengal.
Cork-tree bark,	Quercus suber, ...	Laruch, Rabat, *et cetera*.
Hemlock bark,	Abies canadensis,....	United States.
Sumach,......	Rhus coriaria,........	Sicily.
Valonia,......	Quercus ægilops, ...	Smyrna, Trieste, Morea.
Divi divi,......	Cæsalpinia coriaria, ..	Maracaibo, Rio de la Hache, Savanilla.
Myrobalans,...	Terminalia sp.,......	Bengal.
Algarobilla, ...	Prosopis Pallida, ...	Valparaiso.
Terra japonica,	Acacia catechu,......	East Indies.
Cutch, ...	" "	Calcutta, Singapore.
Kassu, ...	Areca catechu, ...	Ceylon.

Besides the foregoing, which are partly well known in the trade, other astringent substances have been brought before the public, to be employed *per se*, as tanning materials, or with oak bark as an adjunct. These are various extracts from species of the *acacia* tribe: gambier, the extract of the *nuclea gambier*, from Singapore; mangrove bark—*rhizopora mangle*—from Arracan, Malabar, and Singapore; turwar or cassia bark; avaraputtai, Tangada jigota—*cassia auriculata*—from Vizagapatam; saracondraputtai—*cassia fistula*—from Madeira and Tinnevelly; saul-tree bark from the Saul forests; pomegranate rind; darunka pucke—*dadima jegota*—from Kemaon and Vizagapatam; dalumka kho from the vicinity of Calcutta; jamoon-bark—*eugenia jambolana*—and pearl-bark, from Cuttack; samak-bark from Singapore; vangay or gum-kino—*pterocarpus dalbergoides*—from Malabar; kino, or astringent extract of the *Buchanania latifolia*, from the district of Chota, Nagpore; majoophul or gall-nuts—*ficus infectoria*—from Nagore, *et cetera*; tamarisk gall—*tamarix indica*—from Bombay and Lahore; several kinds of myrobalans; gaub, the fruit of the *diospyros glutinosa*, from Calcutta; hag-plum tree—*spondias lutea*—abundant on the banks of the river Berbice, and commonly used in British Guinea for tanning; courida bark—*avicennia nitida*—a tree very common on the Eastern coast of Demerara, *et cetera*.

MORFIT remarks:—1. That tannin is never found to any extent in the interior of the trunk of trees. 2. That it does not exist in poisonous plants, nor in those with a milky or viscid sap. 3. That its proportion is greater in young than in old plants. 4. That the tannin is converted to bitter principle, as the plant increases in age. 5. That it is most abundant in the cortical layers of the bark, and is usually absent altogether in the epidermis. 6. That the proportion of tannin in bark varies with the season, decreasing as the severity of the winter increases; and, 7. That the two extremes of quantity are attained in winter and spring.

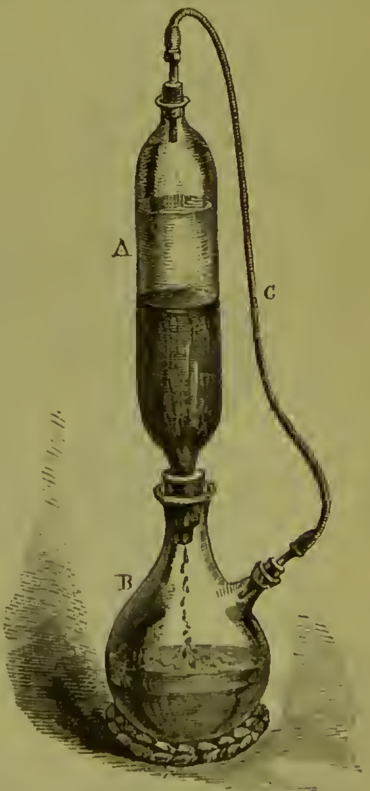
These remarks admit of an important practical application with reference to the most suitable time for the barking of trees, *et cetera*. But before discussing this subject, it will be necessary to enter more minutely into the nature of the tanning principle.

TANNIC ACID OR TANNIN.—By examining any of the numerous substances mentioned above, it will be found that they yield a product which is capable of precipitating a solution of gelatin, and also of giving a greenish or bluish-black one, with solutions of sesquisalts of iron. To matter exhibiting this reaction, and having an astringent taste, the title of *tannin* was given, irrespective of whatever difference might be exhibited upon further comparison. Now, many of those bodies, which in common with the true type of tannin—that which is extracted from galls—precipitate gelatin, and so far show that they are eligible for tanning materials, are known to differ in their characteristics; for instance, some possess acid properties, whilst others are devoid of them; and although towards gelatin their reactions are similar, their atomic constitution is widely different. Regarding their effect in converting skin into leather, this dissimilarity is not so very material as when the components of each are compared. A distinction is also made with respect to the physical appearance of the precipitate they afford with a sesquisalt of iron, and by this all the known tanning materials are divided into two classes. In the first of these are placed gall-nuts and the barks of the several oaks, and the second includes the quinquina, the cachou, gum-kino, pine barks, *et cetera*. The tannin afforded by the first throws down a bluish-black or purple combination, whilst the precipitate afforded by the second is greenish. Experiments have shown that such distinctions are not very marked, since the tannic acid from nut-galls or oak bark, in the presence of an alkali, will occasion a greenish precipitate when added to a sesquisalt of iron, and a bluish or violet compound when acids are present. Hatchett first observed that many plants contain a carbonaceous principle, which, when acted upon by nitric and sulphuric acids, according to the method of Chevreul, yield a substance which, like the tannins of the foregoing barks and fruits, throws down gelatin, and renders it imputrescible. This variety has been designated artificial tannin; but, in the present state of chemical science, it could not be compounded with the natural products. Berzelius, Geiger, Waltl, and Cavallius, are of opinion that tannin, from whatever source it may be obtained, is identical, and that the difference of the reactions with the iron salt must be attributed to impurities which are accidentally present. Stenhouse, in his more recent researches, has shown that such is not the case, but that all those forming precipitates with sesquioxide of iron, varying from the color of that which the tannin of nut-galls affords, must be regarded as a distinct substance, in which case there seems to be an almost endless variety. Even when the iron reactions of some tannins agree, and also appear analogous in other chemical relations, the same chemist states that the composition is frequently diverse. Hence he distinguishes the various kinds of tannin by the source; thus, that obtained from nut-galls he calls from gallotannic acid; from oak bark, quercitannic acid; fustic—*morus tinctoria*—moritannic acid, and the like.

Preparation of Tannic Acid.—It is very difficult to prepare tannic acid of absolute purity, so much so that none of the methods in use for its extraction can afford a product free from foreign matters. When extracting tannin on the small scale, nut-galls are selected, as they yield the largest product. A quantity of these is dried and reduced to powder, and subsequently exhausted of the tannin with water by moistening with this liquid, then subjecting to pressure. The extract thus obtained, if employed with fresh portions of the powdered galls successively, becomes highly saturated with tannic acid. Filtration cannot of itself clarify the opaque inspissated liquid; but on mixing it with a little dilute sulphuric acid, and agitating, a precipitate of the suspended matter forms, and may be removed by filtering it through linen or paper. To the clarified liquid a solution of carbonate of potassa is cautiously added, till it almost ceases to deposit any matter from the menstruum. The crude tannate of potassa thus obtained is separated from the liquid, washed with ice-cold water, or with water at as low a temperature as possible, and dissolved in boiling dilute acetic acid. On cooling the latter, a brownish deposit containing acetic acid parts from it, and must be removed by passing the liquid through the filter. A solution of subacetate of lead is now added to the filtrate, and the resulting tannate of lead, removed and washed thoroughly, then disseminated in water, and a current of sulphide of hydrogen passed through till the whole of the metallic base is converted into sulphide. By evaporating the liquid after the separation of the sulphide of lead in the hollow of a flask, containing some carbonate of potassa, the tannin is procured in the form of gummy transparent scales of a yellowish color. In this state, however, the tannin is still impregnated with a little gallic acid and brownish matter, which may be removed by treating the powdered substance with successive portions of ether. The tannic acid is thus left in combination with the brownish matter; but by repetition of the process, this impurity, as well as the gallic acid, is dissolved out, and the tannic acid remains nearly colorless.

This substance may likewise be prepared by treating the clarified extract of gall-nuts, as above directed, with ammonia till almost neutralized, and to the menstruum chloride of barium is added till it ceases to throw down a precipitate. The flask is then filled with water, and allowed to repose till the whole of the tannate of baryta has deposited. Any gallic acid which may have been formed, remains combined with the base in the supernatant liquid, and may, consequently, be removed by decantation and washing. During these operations, a small portion becomes decomposed and colors the baryta salt greyish; on treating the latter with acetic acid, however, this impurity remains, whilst the tannate of baryta is dissolved. To the liquid thus obtained, subacetate of lead is added, and the plumbous salt proceeded with, as directed above.

Fig. 341.



When the substance is to be obtained in its greatest state of purity, recourse must be had to the process known as that of Pelouze, but which was first broached by Laubert. The latter chemist directed the formation of an extract of sixty grains of powdered nut-galls in one hundred and twenty of ether, the digestion to be continued during twenty-four hours, after which the ethereal extract was to be filtered and evaporated. Pelouze followed the foregoing method in principle by employing the apparatus of Robiquet and Boutron, as used for the preparation of amygdalin. Fig. 341 represents this digester. It is an elongated glass vessel, A.

having an orifice at the top, which is fitted with a ground-glass stopper, and contracting towards the other extremity, which fits tightly into the neck of a bottle or mattrass, B, which receives the extract. Sometimes the lower bottle has a second tubular opening for the purpose of receiving a cork furnished with a tube, to which a connector, C, of caoutchouc is appended, the other end being attached to a similar tube fitted in cork which closes the top orifice. This adaptation causes the filtration to take place much more readily, whilst it prevents contact with any further quantity of air beyond what is contained in the apparatus. The further process is such as already detailed.—See Vol. I. page 581. By careful evaporation—the better if under the exhausted receiver—the tannic acid is obtained in the form of a spongy iridescent, uncrystallizable mass, having a light straw-yellow color. It may be washed with repeated quantities of ether to remove any remaining gallic acid, after which treatment it may be desiccated as previously stated. So prepared, tannic acid is in its purest known state; but as sometimes it results almost colorless, doubtless it is not free from impregnations arising from decomposed tannin—apothema—or some other matter.

Another modification of the method just detailed was introduced by DOMINÉ, and offers the advantage of yielding a larger product, while it admits also of being applied on the large scale for the purposes of the manufacturer. He places the powdered galls in a damp cellar for several days, during which they absorb moisture; the powder is next tranferred to a wide-mouthed jar, and made into a paste with ether—specific gravity 0·75—after this the vessel is hermetically closed, and the contents allowed to digest for twenty-four hours. At the expiration of this time the pasty contents are transferred to a strong linen bag and subjected to gradual pressure, when the ethereal extract of tannin, having a dark sirupy consistence, flows off into the receiver. This liquid must be evaporated to dryness at a gentle heat—100° to 110°—by which the tannic acid is left in the form of light-colored resin-like scales. The compressed residue is further treated with ether, to which six per cent. of water is added in the same manner as when preparing the first extract, and, on expelling the fluid by a gentle heat, a residue of tannin is obtained. It is, indeed, more impure than the product resulting from the method of PELOUZE, as it contains portions of chlorophyl, volatile oil, and gallic acid; still the tannin thus prepared answers very well for medicinal and other uses, for which it is applied in the arts.

Properties of Tannic Acid.—In its purity, tannic acid is colorless, inodorous, possesses a highly astringent taste, and is very soluble in water. It is, however, devoid of all bitterness, notwithstanding its astringency is so powerful. On testing the aqueous solution with litmus, the reaction evidences the acid nature of the tannin; and further, by treatment with an alkaline carbonate, carbonic acid is freely displaced, showing that a combination of the alkaline base and the tannin has taken place. With the oxides of the heavy metals it in a great measure combines, giving rise to precipitates which are the tannates of the respective bases, and generally possess a color more or less remarkable. Thus an infusion of nut-galls reacts in the following manner:—

With a *neutral* solution of salts of

	Precipitates given.	
	Brande.	Dumas.
Protoxide of manganese,	Dirty-yellow.	—
" iron,	Purple-tint.	—
Sesquioxide of iron,	Black.	Blue-black.
Oxide of zinc,	Dirty-yellow.	—
" tin,	Straw-yellow.	Yellowish.
Binoxide,	Fawn-yellow.	Yellowish.
Oxide of cadmium,	—	—
" copper—protochloride,	Yellow-brown.	Grey.
" " —protonitrate,	Green.	Grey.
Oxide of lead,	Dingy-yellow.	White.
Teroxide of antimony—from emetic tartar,	Straw-yellow.	White.
Teroxide of bismuth,	Yellow.	Orange.
Oxide of cobalt,	—	Yellowish-white.
Salts of cerium,	—	Yellowish.
" titanium,	—	Blood-color.
" tellurium,	—	Isabelle-yellow.
" chromium,	—	Brown.
" tantalum,	—	Orange.
" molybdenum,	—	Brown.
" uranium,	—	Brownish-red.
" silver,	—	Pale-yellow.
" platinum,	—	Greenish-shade.
" gold,	—	Brown.
" osmium,	—	Bluish-purple.

In making the foregoing experiments, it is necessary to employ neutral solutions of the salts, otherwise any excess of the acid may not only alter the shade of the precipitate, but prevent it altogether. This is especially the case with salts of iron and of titanium. When a solution of tannic acid is added to another of protosulphate of iron, according to DUMAS, no precipitate occurs; but if one of the sesquisulphate be substituted, there is an abundant deposit of a blue-black color.

By exposing an aqueous solution of tannic acid to the air, at a moderately elevated degree of heat, oxygen is freely absorbed, and an equal volume of carbonic acid is disengaged. Upon examination, the matter in solution will be found to be wholly transformed into two other substances, gallic and ellagic acids, the former of which is in excess, and is dissolved in the liquid, whilst the latter remains insoluble in the form of a yellowish powder.

This transformation takes place in the aqueous extract of gall-nuts much more readily than in one of pure tannin; this is particularly the case if the mares or insoluble residue of the galls be left in contact with the liquid, as it induces a fermentative action, which brings about the transformation the more readily. When boiled with sulphuric or hydrochloric acid, gallic acid is also formed, together with grape sugar, which, as STRECKER states, remains in the mother liquid after the newly-formed acid is removed by crystallization. The change here induced may be represented thus, according to MILLER :—

$$\underbrace{C_{54}\,H_{32}\,O_{34}}_{\text{Gallotannic acid.}} \quad + \quad \underbrace{10\,HO}_{\text{Water.}} \quad = \quad 3\,(\underbrace{C_{14}\,H_3\,O_7,\,3\,HO}_{\text{Gallic acid.}})$$

$$+ \quad \underbrace{C_{12}\,H_{12}\,O_{12}}_{\text{Glucose.}}.\ 2\ \text{aq.}$$

A concentrated solution of caustic potassa at the boiling point has also the effect of transforming tannic into gallic acid; and if air or oxygen be admitted, of converting the latter into an ulmin-like substance. Hydrochloric, nitric, phosphoric, and arsenic acids, occasion in strong solutions of tannic acid white precipitates, which are, as stated by BERZELIUS, compounds of the tannin with those acids respectively. All these precipitates are, however, readily decomposed, and their tannin changed into gallic acid, by seething them with dilute sulphuric acid or with an excess of alkali. If a cold aqueous solution of tannin be mixed with another of gelatin, isinglass, bone-size, or glue in excess, an opaque white precipitate is obtained of tanno-gelatin, that is soluble by the aid of heat in the supernatant fluid. When, however, the conditions are reversed, and an excess of tannin is taken, it happens that instead of dissolving, the precipitate agglutinates, and forms a membranous matter of a greyish hue, that possesses considerable elasticity, and thus approximates to caoutchouc. The solutions filtered from these bodies strongly tinge those of the sesquisalts of iron. It appears that tannin solutions react in a similar way with protein compounds in general.

It was thought for a long time that the insolubility of the tanno-gelatin offered a means for insuring the purity of tannic acid, and of detecting the absence or presence of gallic acid in the sources affording tannin; but this insolubility, excepting in water alone, does not answer the purpose. PELOUZE employed a piece of skin, cleaned in the ordinary way from hair and epidermis; this was immersed for some hours in the extract, and the whole agitated occasionally, and finally the liquid filtered. When pure tannic acid was operated upon, the whole combined with the integument, so that the fluid had no astringent taste, nor did it color a solution of a sesquisalt of iron; but if gallic acid had been mixed with it, the bluish-black tint would present itself in the latter case.

Freshly precipitated alumina, agitated with a solution of tannin, absorbs the latter rapidly, and forms with it an insoluble composition; gallic acid behaves in a similar manner. At the temperature of an oil bath, tannic acid is decomposed, water and carbonic acid being formed; but when the heat is increased, other products are generated, and nothing remains but charcoal, which, if heated on platinum wire, burns, leaving no residue. Strong ether dissolves tannin, and forms a sirupy liquid, which does not combine with fresh ether. Alcohol behaves with tannin in the same way, the solvent power of the spirit decreasing in reference to it as it approaches purity or dehydration.

From the analysis of BERZELIUS, it appeared that tannin was composed centesimally as follows :—

	Berzelius.		Pelouze.
Carbon, ...	52·69	....	51·40
Hydrogen,................. ..	3·86	....	3·51
Oxygen,......................	43·45	....	45·09
	100·00		100·00

These numbers nearly correspond with the formulæ, $C_{18}\,H_8\,O_{12} = C_{18}\,H_5\,O_9,\ 3\,HO$; but STRECKER in his later researches gives the equation for gallo-tannic acid thus, $C_{54}\,H_{22}\,O_{34}$, showing that it contains less oxygen and hydrogen than is indicated above.

Varieties of Tannin.—As already stated, recent investigations have a tendency to the conclusion that tannin from the various vegetal products manifests such difference in its reactions with several substances, as to justify the recognition of many varieties of this compound, though classed under the above generic name. The impurity of this body was long considered to affect its behavior with reagents so as to vary the reaction; but, latterly, STENHOUSE and others have arrived at other conclusions, and regard the tannins from the different sources, and which give unlike reactions with reagents, as distinct chemical bodies. Doubtless, the other extractive matters in the solutions of the tannin modify to a great extent the color of the precipitate or other characteristics, from those afforded by the pure tannin, but all the difference cannot be attributed to this cause. With gelatin many of the tannins give well-marked indications, which would go far to show the dissimilarity in the nature of the tannin; yet it is upon their behavior with a solution of sesquisalt of iron that the discrimination is based. To ascertain this point, STENHOUSE prepared a reagent which affords indications only with the variety of tannin contained in galls and with gallic acid, and which consists in the production of pyrogallic acid when the body to be tested is submitted to the destructive distillation. In this way he observed that many varieties, which comported themselves exactly similar with sulphate of iron and in their general reactions, are by no means identical. Taking the behavior with solutions of sesquisalts of iron as the criterion, the following varieties are detected :—

1. *Tannin which forms a bluish-black precipitate in solutions of a sesquisalt of iron:*—Tannin from nut-galls, oak, poplar, beech, hazel, chestnut, maple, cherry, apricot, plum, elder, and other barks; sumach and logwood; from the roots of *lithrum salicana, iris pseudacorus, geum urbanum; polygonum bistortum*—bistort; *alchemilla vulgaris*—ladies' mantle; from the leaves of the *arbutus uva ursi*—bearberry; *amothera biennis, geranium pratense;* from the husks of the *cæsalpina coriaria;* from lentils, *et cetera.*

2. *Tannin which forms a green precipitate in solu-*

tions of sesquisalts of iron:—Tannin from catechu—juice of the *mimosa catechu;* gum-kino—juice of the *coccoloba uvifera;* most of the cinchona barks; horse-chestnut bark; the roots of the *rumex aquaticus*—water-dock; *tormentilla erecta*—septfoil; *krameria triandria*—ratany; *polypodium filex mas*—male fern; tea and badian; a species of anise; the leaves of *salvia officinalis*—sage; and of *arnica montana*—leopard's bane, and in date-stones.—*Morfit.*

Artificial Tannin.—Besides the foregoing, chemists distinguish other varieties of tannin which result from the chemical action of several powerful agents upon many substances; as, for instance, from the action of nitric acid upon charcoal and indigo, and likewise from the effects of sulphuric acid upon resins and camphor. The first notice of artificial tannin was published by HATCHETT in the Transactions of the Royal Society in 1801: he discovered it whilst making experiments upon the slow carbonization of plants. This tannin is different, however, from other varieties of this substance at present known. When one part of charcoal, reduced to an impalpable powder, is digested with five parts of nitric acid of spec. grav. 1·40, and ten of water at a moderate heat, the fluid being added portionwise to the charcoal, the latter after a time disappears, and a transparent deep-brown liquor remains, which, on evaporation, leaves the artificial tannin slightly impregnated with acid. By repeated solutions in water, and evaporations, this impurity may be removed. From the above materials about 1·2 of artificial tannin is obtained.

Artificial tannin prepared in this way is a brown, inodorous substance, having a vitreous fracture, and very soluble in water. THOMSON states that alcohol of spec. grav. 0·80 dissolves it, and so far it manifests a difference of behavior from natural tannin. The aqueous solution of this substance precipitates gelatin of a brown color, but the shade deepens as the liquids are more dense. This precipitate is a compound of tannin and gelatin, in the proportion of thirty-six parts of the former to sixty-four of the latter. It is insoluble both in hot and cold water. With the alkaline bases it combines, forming more highly-colored solutions, which, in the course of some time, get cloudy. The ammoniacal solution of artificial tannin, on being evaporated to dryness and redissolved, will not precipitate with gelatin till after the alkali which it retained is neutralized with an acid. The alkaline earths precipitate it, but the precipitates are slightly soluble in water; the heavy oxides throw it down in combination as a puce-colored substance. On treating the precipitate with nitric acid, the artificial tannin dissolves without change, whereas the natural product is altered by this agent. Heated alone in a retort, it yields water and nitric acid, ammonia, carbonic acid, and another gaseous substance, probably nitrogen. According to CHEVREUL, this variety of tannin is a compound of nitrous or nitric acid with a carbonaceous matter.

A second kind of tannin is produced when indigo, or similar compounds rich in carbon, are treated with nitric acid, as in the foregoing method. A very bitter, orange-colored residue is obtained, which is soluble in water, precipitates gelatin and metallic bases, and affords, when decomposed, nitrous or nitric acid. If sulphuric acid be made to react upon resin or camphor till these dissolve, and heat be applied till the liquor blackens, and then cold water added, a black powder falls which, when treated with alcohol and the spiritous extract evaporated, yields a residue which is a third kind of tannin compound. This variety precipitates gelatin and some of the bases. CHEVREUL considers that the compound contains sulphide of hydrogen.

Uses of Tannin.—The range of the application of tannic acid is not very extensive. It will be already understood to be of primary importance in the manufacture of leather; but, besides this application, it serves another purpose in wine-growing countries, namely, of precipitating the *glaiadine* from the fermented *must*, especially of white wines. The removal of this principle is of very great importance to the vintner, for if it be suffered to remain, it is apt to induce a secondary viscous fermentation, which would destroy the wine. Tannic acid seems to be the best antidote in this instance, since it coagulates the glaiadine, and forms a tannate with it. Tannic acid is also extensively employed as a medicine on account of its powerful astringent properties, which are readily explained by what has been said regarding its action on albumen, fibrin, and gelatin. Its effects are to check hæmorrhages, profuse secretions, and to constringe relaxed fibres; and for either purpose it may be adminstered either internally or externally. When taken into the system, it would appear that it is capable of being converted into gallic acid, pyrogallic acid, and a humus-like substance, all of which may be detected in the urine; but this change does not seem to have been effected till the tannin has exhibited its peculiar astringent action. In the laboratory, tannic acid is occasionally employed as a test.

GALLIC ACID.—The tendency of tannic to be transformed into gallic acid has been already mentioned: but it may be well to show more in detail the circumstances under which this change is effected, and to point out the properties of gallic acid generally, as also with regard to the operations of the tanner. Its name has been derived, as is evident, from galls, on account of those excrescences containing it ready-formed; it likewise exists in the cypress-nut, arnica flowers, white hellebore, meadow saffron—*colchicum autumnale*—and in a number of astringent barks, together with tannic acid, but in small quantities. Its most prolific source is tannic acid, which, by oxidation, yields it abundantly. The conditions affecting the change, such as exposure of the solution of tannin to air and at an increased temperature, have been already mentioned, as likewise the decomposition of the same body by the mineral acids. All the methods recommended for the production of gallic acid from tannin, are based upon these properties of the latter. Thus BRACONNOT prepares it from powdered nut-galls, by drenching this substance with water and maintaining a temperature of 70° to 75°. After a while a quiet action succeeds, and when this subsides the pasty mass is to be expressed and afterwards heated with boiling water, which dissolves out the gallic acid, and yields it upon evaporation in impure crystals. These, by re-solution in water and filtration of the liquid through animal charcoal, afford a menstruum which gives the gallic acid in a state of purity when concentrated. WITHELL prepares it by treating thirteen drachms of dry tannin with two fluid ounces of sulphuric acid of 1·84°, diluted with four times its volume of water and the application of a boiling heat. Gallic acid in crystals is deposited to the amount of eighty per cent. of the tannin employed.

It would appear from various researches, that the change of tannin to gallic acid, on exposing the extract containing the former to air and moisture, is due to a fermentative process, which is considerably expedited if the vegetal matter in the bark or gall, or whatever else the source may be, is permitted to remain in contact with the liquid. Such is the case, especially, with extract of gall-nuts; and it might be inferred that the tannin from all other sources, and which is capable of being transformed into gallic acid by oxidation in the above manner, is similarly affected. M. LAROCHE, has shown by comparative experiments the effect of the marcs of gall-nuts, after the extraction of the tannin with ether in the ordinary way, in operating this change. By inclosing an aqueous solution of tannin and a portion of this residue in a bottle or flask, and allowing it to remain for some time, he found that the tannin was entirely converted into gallic acid, whilst a strong extract of tannin, freely exposed to the air at the same time, retained nearly the whole of its tannin unaltered. Hence, doubtless, the insoluble matter in galls in the presence of moisture, is capable of acting on tannin as a ferment, and that the change of tannin into its derivative is the result of a fermentation. It is well known that fermentation by contact of yeast, blood, and albumen, effects the same transformation of the astringent extract as the residue of the galls which have been digested in ether, and also that the latter will excite the vinous fermentation in solutions of grape-sugar, and, therefore, these reactions may be taken as mutually corroborative. Further, the gallic fermentation may be intercepted by antiseptics, like the vinous. Protochloride of mercury—corrosive sublimate—completely prevents the decomposition; and pyroligneous acid, or carbonic acid, as shown by the investigation of CALVERT, on account of some empyreumatic matter which it contains, likewise considerably retards the fermentation.

It has been shown, that sulphuric and hydrochloric acids at a boiling heat rapidly change tannin into gallic acid, and without the intervention of air; but if the mixture be kept at a common temperature, M. ANTOINE has shown by his researches that the decomposition of the tannin is retarded by a small portion of those acids. On the contrary, tartaric, malic, and vegetal acids in general, expedite the decomposition of the tannin. The rapidity with which sumac ferments, may be referred to the quantity of malic acid in the leaves.—*Parnell.*

Properties of Gallic Acid.—When pure, this acid crystallizes in long silky needles, which are unalterable in the air; its taste is acrid and styptic. BRACONNOT states that it dissolves in a hundred parts of cold, and in about three parts of hot water; four or five parts of alcohol in the cold dissolve it, but one part of the hot spirit will take it up. It is soluble in ether, but in less quantity. The aqueous and spiritous solutions, but the former more readily, undergo decomposition, so that the surface of the liquid becomes mouldy, and a brownish matter is produced, which DÖBEREINER considered ulmin. Added to a solution of gelatin, no precipitation occurs—a behavior which at once distinguishes gallic from tannic acid, and which indicates that it is unavailable in converting skin into leather. This being so, and, as has been already pointed out, tannin being readily convertible into this body, it becomes of the utmost importance to the tanner to guard against this transformation, which, in the usual way of tanning, is so apt to take place. The researches of LAROCQUE have shown that, in regard of the tannin from galls, the decomposition is completely and readily effected, provided the insoluble residuary matter be allowed to remain in contact with the liquor containing the tannic acid, and it is equally well known that the tannin from sumac is liable to decomposition, as well when it remains in contact with the insoluble portion of this body, as when it is separated from it; but independently of the action of the residue, the malic acid here plays an important part. Though the evidence proving that the insoluble portion of the barks, *et cetera*, employed in tanning, when allowed to remain in the tan-liquor, does operate in the rapid conversion of tannin into gallic acid, thereby rendering the former valuable body useless, is not definite,—still, knowing that in the waste tan-liquor, a large quantity of gallic acid is found, it may be safely stated that its production is from the tanning, and also is owing more to the effects of the insoluble matter of the source of the tannin, than to any oxidation which might take place during the tanning processes. Even those kinds of tannin which are incapable of producing gallic acid by decomposition are subject to a metamorphosis which destroys the tanning agent, and this fermenting action is more readily produced when the insoluble matter is left in contact, than if the liquor were retained by itself. The only benefit which the tanner derives from gallic acid is, that it aids in swelling the hides, and thus facilitates the absorption of the tannin; but when it is considered that a dilute solution of sulphuric or vegetal acids effect the same thing quite as well, it will be evident that he who relies on the swelling by gallic acid, and sacrifices a corresponding portion of tannin in its production, suffers a considerable loss, and is not fit to compete with those who can obviate such a sacrifice.

At 410° to 420°, according to the observation of PELOUZE, gallic acid is entirely volatilized, producing a sublimate of beautiful white crystals and pure carbonic acid; if the heat be urged to 464° or 482°, instead of the foregoing change, another takes place, in which pure carbonic acid is likewise developed. But in addition to this a quantity of water is produced, and which runs along the sides of the retort, in the bottom of which remains a considerable mass of brilliant-black insoluble matter, which at first sight might be taken for charcoal. It is, however, a true acid, and is called by PELOUZE, meta-gallic acid.

According to the above-named chemist, crystallized gallic acid is composed of—

	Centesimally.
Carbon,	50·10
Hydrogen,	3.64
Oxygen,	46·26
	100·00

numbers which agree with the formula, $C_7\ H_3\ O_5,\ HO$; STRECKER, however, regards it as a tribasic acid, thus $C_{14}\ H_6\ O_{10},\ 2HO = 3\ HO,\ C_{14}\ H_3\ O_7,\ 2\ aq.$—and capable of forming salts which correspond with the general formula, $MO,\ 2\ HO,\ C_{14}\ H_3\ O_7$; $2\ MO,\ HO,\ C_{14}\ H_3\ O_7$, and $3\ MO,\ C_{14}\ H_3\ O_7$; MO being here the representative of a metallic oxide.

As pyrogallic acid, $C_7\ H_3\ O_3$ or $C_{14}\ H_6\ O_6$, meta-gallic acid, $C_7\ H_2\ O_2$ or $C_{14}\ H_4\ O_4$, ellagic acid, $C_{14}\ H_2\ O_7,\ HO$, and other derivatives from gallic acid and, therefore, remotely from tannic acid, are of no importance in the making of leather, they will not be further dwelt upon. Ellagic acid is said, however, to be the chief agent that gives the *bloom* to the tanned hide.

SUBSTANCES USED IN TANNING.—Those which are available for the purposes of tanning, embrace a wide range if the juices, barks, leaves, roots, fruit, and excrescences of trees, and also vegetals which contain tannin of one kind or other, be taken into account. In looking over the researches and labors of chemists, many hundred substances which yield tannin have been discovered; but practice, or the trade, recognizes only a few of these, probably owing to the quantity which can be annually produced, their yield of tannin, or because they offer some advantage either in making a better leather, or in the time required to effect the operation. The tannin and other distinct principles in vegetal growth of every kind, are derived from the sap or soluble matters, imbibed by the rootlets from the soil in which the plant exists, and the gases absorbed by the foliage. In many plants which elaborate tannin, it is met with in small proportions, owing perhaps to its being only a secondary, and not a primary secretion. It is found in some vegetals equally in all parts, whilst in others certain parts are richer in this substance, the remaining exhibiting only slight indications of its presence. The particular portions of plants that yield the greatest amount of tannin are, therefore, preferred in making leather.

The following is a list of the materials which contain tannin in the largest quantities, and which may be employed in the manufacture of leather.

INSPISSATED AND PREPARED EXTRACTS,	Kino, Catechu, *Terra japonica*, or Cutch.
VEGETAL EXCRESCENCES,	Galls.
TREE LEAVES,	Of the different kinds of willow. Of the *quercus robur*—common oak; *quercus cerris*—Turkey oak; *quercus ilex*—evergreen oak—and other varieties. Of the *erica vulgaris*, or common heath, and of other varieties of the same plant. Of the *cyndra scolymus*—garden artichoke. Of the sloe-tree—*prunus spinosa.* Of the *conium maculata*—spotted hemlock. Of the *arbutus uva ursi*—bear-berry. Of the *thea Chinensis*—the leaves of the several varieties of green and black teas yield tannin—and of the *rhus glabrum*, known as *sumac.*
FLOWERS AND TREE TOPS, FRUITS,	These are hardly ever employed, although many afford extracts which precipitate gelatin and salts of iron.
SEEDS AND BULBS,	Of the grape. Of the *hydro-sapathum* and wild cornel. The hulls of the fruit of the *cæsalpina coriaria*, known under the title of divi-divi, or leby-diby. The bulbs of the *scuilla maritima.* The dried acorn hulls of the prickly-cupped oak—*quercus ægilops.*
WOODS,	All woods or trees, the barks of which yield tannin, also afford more or less of this substance; they are, however, scarcely ever employed.
ROOTS,	Of the deutillaria, or lead-wort—*plumbago Europæa.* Of the male fern—*aspidium filex mas.* Ratany—*krameria triandria*—root. Of leopard's bane—*arnica montana.* Of statice, or marsh rosemary.
BARKS,	Common bark, of which there are several varieties; birch, chestnut, and horse-chestnut barks; sassafras, or the bark of the root of the *laurus sassafras;* larch, hazel, beech, Lombardy poplar, blackthorn, pomegranate, ash, elm, cork-tree, cinchona, willow, sycamore, tulip-tree, wattle and oak barks; besides these, however, there are other barks—such as that of the sumac shrub, winter's bark, *et cetera*—that afford tannin in available quantities.

It will not be uninteresting to state briefly some of the properties of the substances mentioned in the foregoing table, with respect to their uses for tanning purposes.

KINO.—Of the inspissated extracts which are found in the market, kino or gum-kino, is the richest in tannin, containing, as it does, according to VAUQUELIN'S analysis, seventy-five per cent. of this compound. Nevertheless, it has not hitherto come into use for tanning purposes, but is solely devoted to medical uses. For its more general properties, refer to page 316, Vol. II.

CATECHU.—Catechu is another of the same class as the preceding, and forms a most useful article for the tanner. There are several varieties which are distinguished by various names, such as cutch, terra japonica, and gambir. Formerly, this extract, from its brownish-red color, was supposed to be a kind of earth, hence the title *terra* given to it. Catechu is extracted from the acacia catechu, a tree which grows to the height of twenty or thirty feet, and abounds in the forests from latitude 26° to 30°, known as the Bornese territory on the Malabar coast, and called Cancan. The heart and bark of the wood are boiled in water, and the solution evaporated, which leaves the astringent extract known as Cancan catechu. According to NEES VON ESENBECK, most of the catechu exported from Bombay is prepared from the acacia catechu, whilst that brought from Bengal, is derived from the *uncaria gambir*, a shrub cultivated in the countries lying on both sides of the shores of Malacca. It is obtained by boiling the wood, bark, and leaves of this shrub together with the inspissated juice in water, and evaporating, then adding a little sago to give it consistency; it is finally exsiccated in the sun, and then cut into square or circular cakes to suit the purchaser. Bombay catechu, which is the richest in tannin, is of a dark brownish-red hue, both externally and internally, and possesses a specific gravity of 1·38. DAVY examined the Cancan catechu, and found it to be 1·39; he also found in two hundred parts of this, as well as of the Bengal catechu, and known by the title *Pegu*, from the province of Bengal where it is prepared, the following constituents:—

	Concan or Bombay catechu.	Pegu or Bengal catechu.
Tannin,	109	97
Extractive,	68	73
Mucilage,	13	16
Earthy residue,	10	14
	200	200

The genuine catechu, of whatever variety, contains, on an average, about half its weight of tannin, and its efficacy in making skin into leather, has been estimated as being five times greater than the best oak bark; but this seems exaggerated. Besides the real tannin, the extractive matter contained in it is another definite substance, which is called *catechin* or *catechuic acid*, and which, doubtless, plays a part in the process of tanning. To it is ascribed the property of coloring the leather so deeply. The latter body differs from the tannin in being insoluble in cold water, although a solution of the tannin of catechu takes up a small quantity of it. The varieties of catechu of commerce are:—

1. *Cake catechu*, from its being in circular cakes. Their color varies from a light-brown to a black, and their weight from several ounces to two pounds.

2. *Pegu catechu.*—As already stated, this variety obtains its name from the province where it is prepared. It is generally imported in masses of a hundred pounds weight, but as seen in the shops, it presents the appearance of angular irregular fragments in double layers, with leaves between. It has a compact shining fracture, and a deep-brown color.

3. *Bengal catechu* is manufactured in rectangular cakes, but in the course of transit they get reduced to fragments. Externally, it has a rusty brown color, and internally, the shade varies from a brownish-grey to dark-brown.

4. *Bombay catechu.*—This variety occurs in globular lumps of the size of an orange flattened, and two pieces generally adhering together. In color it resembles that brought from Bengal.

5. *Gambir.*—It is stated by M'CULLOCH that no less than four thousand six hundred tons of catechu, under the name of *gambir*, is produced annually by the Chinese settlers in Rhio. It takes its name from the shrub which is its source, the *uncaria* or *nuclea gambir.* It has a deep yellow or reddish-brown color on the outside, but within it is paler, and presents a dull earthy fracture. It comes to these countries in solids of about a cubic inch. ESENBECK, who examined this variety, states that it yields from thirty-six to forty per cent. of tannin. Boiling water entirely dissolves it.

6. *Arecha catechu.*—The nuts of an Indian palm known by this title, afford this kind of astringent substance. These fruits are macerated with water, and the decoction evaporated, when a better sort of catechu results, known by the term *kassu*, and the semi-exhausted residue upon further treating it with water, affords a solid extract, which is distinguished as *coury*. The former is of a black color, and intermixed with husks, and the latter of a yellowish-brown, with an earthy fracture. The *coury* is, of course, inferior to extract known as *kassu*.

With regard to the application of catechu to the manufacture of leather, the natives of India have long practised it; but its introduction into the trade of this country for a similar purpose, is of modern date. Its richness in the tanning agent causes it to be very rapid in producing a gelatino-tannate of the substance of the skin, or, in other words, of making leather. The qualities of the article manufactured from it, are not, however, so satisfactory as the rapidity of its effects, either to the tanner or the public: for the leather is very permeable to water, light and spongy, hard, and of a dark-reddish fawn color. The characteristic deposit from oak bark and a few other tanning agents, known as *bloom*, is not produced by catechu, and this want is a material objection to its use, as the existence of *bloom* upon leather is considered as a kind of guarantee of its goodness. One pound of catechu, of first-rate quality, is capable of producing one pound of leather, and, consequently, in tanning power is equivalent to five of oak bark, or thereabouts, as already stated.

Besides the inspissated juices just mentioned, there is another which, though not yet introduced into the European trade, has, nevertheless, been employed by the North-western Indians for tanning purposes. This is gum-butea, the account of which will be found at page 315, Vol. II.

GALLS.—There is no other natural product that affords so much tannin as those round, hard, woody excrescences known as galls. Formerly it was supposed that these were a kind of fruit; but naturalists and physiologists have ascertained that this is not the case, but that they are excrescences or tumors which form on the branches of different trees and vegetals, owing to the puncture of certain insects, for the purpose of depositing their eggs. The tree which affords those galls that are commonly known as *nut*-galls, is a stunted species of oak—*quercus infectoria*—which is very general throughout Asia Minor. It grows to the height of four or six feet, has a crooked stem, and yields an acorn two or three times larger than its cup. The gall-flies, which occasion the gall, belong to the genus *cynips*, and, from different accounts, there are several species; that which is concerned in producing the officinal galls, is the *cynips gallæ tinctoriæ*. The female insect of this variety, by means of an appropriate apparatus, perforates the cortical part of the plant, and in the wound deposits her eggs, together with an acrid liquor. In two or three days the part is, as it were, inflamed, and a swelling appears, and continues to increase till it results in a gall. The eggs which are inclosed in this excrescence are hatched, and in due time the young larvæ appear, and develop themselves, being supported by the juices of the plant till they become a perfect insect, when they perforate the gall and escape. When this happens, the excrescence loses much of its astringent principle, and becomes lighter; but if gathered or harvested before the entombed insect is completely developed, the nuts are not only heavier, but are richer in tannin, and command a better price in the market. Galls gathered before the escape of the insect, have a black or bluish shade, but when the insect has left, their color is paler, and they generally attain to a larger size. To prevent this occurrence, great care is taken to harvest the galls before the insect attains its full growth, and eats its way through, leaving them, however, on the trees till they have acquired their greatest weight. In some parts the governor, or *aga* of the district, levies a tax on the produce; and being thus interested in the success of the crop, he causes the cultivators to traverse frequently the hills and mountains to report upon the advanced state of the galls, and wherever the proper growth has been attained, they are immediately collected. The selections thus made are known in the market as *green-galls*, and come to these countries from Aleppo, Smyrna, and the interior of Asia Minor. Those which escape harvesting before the entombed insect has attained its full growth or emerged, are known as *white-galls*, and are imported from the same place. Another kind of gall, produced upon the oaks growing in many departments in France. are nearly equal in size to the Asiatic green-galls, but they are rounder, and possess a smooth and in some instances a polished surface. They have a brownish color, and rank in their content of tannin intermediate between the green and white Aleppo galls. A variety originating from the puncture of an insect allied to the *aphis* on the branches and shoots of the *distylium racemosum* comes from Japan. They are of an irregular shape, having in some instances both ends small, whilst the middle is much thicker, but more generally the stem end is the least and the more swollen part is near the other. Hence they are called commercially apple-galls.

Annexed are the analyses of samples of Aleppo and Chinese galls by two distinguished authorities:—

	Aleppo galls.			Chinese galls.
	By Guibourt.	By Davy.		By Bley.
Tannin,	65·0	26·0		69·00
Gallic acid,	2·0	6·2		4·00
Ellagic acid,	2·0	—	Fat albumen and resin.	3·00
Brown extractive,	2·5	—		
Starch,	2·0	2·4		
Gum,	2·5		Cellular matter.	16·00
Sugar,	1·3			
Chlorophyl and volatile oil,	0·7	—		—
Woody fibre,	10·5	65·4		—
Water,	11·5			8·00
	100·0	100·0		100·00

Leaves.—Of the foliage of trees containing tannin, very few, if any, are now employed in the manufacture of leather. The leaves of the heath were once extensively used in this country; but this material has long been abandoned, preference being given to oak barks and other substances of native and foreign growth.

The leaves of the sloe-tree—*prunus spinosa*—were likewise used to some extent in London for tanning calf skins, by employing a decoction prepared by boiling the leaves in barley water. So also it is stated in the *Bibliothèque Physico Economique* for 1789, that garden artichoke was resorted to for preparing calf and goatskins for bookbinders' use, and that the operation was as successful as if nut-galls or willow bark had been the tanning agent.

The various species of tea yield variable but large quantities of tannin, amounting from thirteen per cent., according to Mulder—to thirty-five and even forty per cent., according to Franck. The value of this article, however, as a luxury and dietary, precludes its employment in the production of leather.

Sumac.—In its purity it consists of the powdered leaves of a shrub that grows extensively in the south of Europe, in the United States, and in Asia to which it is indigenous. It seems that there are several species such as the *rhus cotinus*—wild olive—*rhus glabrum* or *coriaria*, which is the best and most esteemed for the preparation of the finer kinds of leather. Italy, Sicily, Portugal, Spain, and France produce considerable quantities of sumac, varying in quality, and distinguished from one another by the habits of the tree. the color, and other properties. The sumac obtained from the *rhus cotinus* is for the most part employed in dyeing, and the product of the *rhus coriaria* is that which is converted to the uses of the tanner, especially in the preparation of morocco and similar leather. The latter shrub which grows wild in Portugal, Spain, and other countries named above, rises to the height of four to eight, and in some cases to twelve feet; its stem is crooked and covered with a reddish-grey bark; the leaves present a green on the upper and a whitish color on the under surface during spring and summer, but they assume a reddish hue in autumn. It flowers in July, the blossom being greenish-red, and yields a cluster of small crimson berries on ripening. Regarding the effect of sumac as a tanning agent, it is stated that it deprives the skin of much of its softness and elasticity, but it offers one great advantage of not coloring it during the process, and is on this account preferred in France and other places, notwithstanding its cost being much greater than other tanning agents, by the fabricators of morocco and glazed leather. It is utilized in the ordinary way of tanning mixed with bark or other matter, and affords good results.

Of the species of sumac in the market, the Sicilian is accounted the best. There are two kinds, one of which, the Alcamo, is the most esteemed. It is a very fine light-green powder, containing very little woody matter, having an agreeable odor analogous to that of the violet, and a strong astringent taste; it contains very little coloring matter, though it gives a yellowish green solution when macerated with water. The second variety inclines to a reddish yellow, has a feebler odor, with a less astringent taste than the foregoing variety. On this account it is not much employed in tanning, though extensively used in dyeing; see vol. i. pp. 579, 629. Sicilian sumac is generally packed in bales weighing about one hundred and a half.

Spanish sumac is various in quality, being less carefully prepared, and, consequently, more or less mixed with woody matter. The best sort comes from Priego, and is grown in the neighborhood of Malaga. It is, like the Sicilian, finely ground, and affords a color of equal or greater brightness; its odor reminds one of the tea plant. With water it gives a dark and more reddish solution than the foregoing. It is usually packed in bales of one hundredweight. The other sorts, the Molina and Valladolid sumac, are next in quality to the foregoing; they are very similar.

Portuguese or Porto sumac is almost similar to the Priego, but is generally dirtier, and contains more mineral salts.

Italian sumac has a dark-green color, is free from woody matter, but feels granular in the hand, and has an odor like that of the bark, which possesses similar qualities as the leaves.

French sumac is similar to the preceding. Three sorts are collected, the Fauvis is almost equal to the Sicilian when well purified, and comes from Brignolles, near Marseilles. If less care be taken in its manufacture, it approaches more to the quality of Malaga sumac. It frequently goes under both these names. A second sort, Donzere, and a third, Pudis, are commonly used in the tanneries. A fourth variety, called *redou* or *redoul*, obtained from the *coriaria myrtifolia*, cultivated in Languedoc, is of a greyish-green color.

The operations involved in the preparation of sumac, consist in collecting the branches of the shrub whilst in full foliage, drying them in the sun, and then separating the leaves by threshing, or other means. Subsequently the detached leaves are ground under vertical mill-stones, and packed in bales for the market. In some cases, the peduncles and more tender branches are ground with the leaves; but as these contain a good deal of tanning material, they do not so much injure the quality.

FLOWERS AND FRUITS— *Valonia.*—Hitherto flowers and flower-tops, though containing tannin, have not been used in the preparation of leather on the large scale. The same might be said of fruits, with the exception of the acorn-cups of the *quercus ægilops* —prickly-cupped oak,—a tree which grows in abundance in the Morea and the adjacent countries. In commerce, they pass under the title *valonia*, and are imported from Turkey, Greece, Italy, and India. When the fruit is gathered, it is conveyed to the nearest port to be shipped; there it is stored in a warehouse during several months, being laid out in beds of three to five feet in thickness. A slight heating or fermentation sets in during the above period, and as the moisture escapes, the long spreading scales, which hitherto confined the acorn become contracted, and allow the latter to fall out of the cup. After being well dried the whole is picked, and the acorns which contain no tannin and the damaged cups are separated from those of the latter that are dry and good. The cup of this acorn, so long as kept dry, retains a bright drab color; but when exposed to moisture, it loses this appearance and turns black, losing by the change its tanning properties. Doubtless, to the long exposure of the upper cups to the disengaged vapor from the bed, is owing their being invariably more or less damaged. Ordinary or common valonia, the cups of which average about two inches diameter, differs from that kind known as camata, or *camatena valonia*, which are only about the size of a large cherry. The latter is said to be the fruit of a smaller species of *quercus* than that which affords the common valonia. It is in greater demand for silk-dyeing than for tanning.

Leather prepared with valonia is said to be harder and less permeable to water than that made with oak-bark; and, besides, it presents the advantage of readily depositing a rich bloom upon the leather, a characteristic much sought by the traders in this article. Not less than from ten to twelve thousand tons of this tanning agent are annually imported into Great Britain and Ireland, and it is stated that two pounds of good average quality are sufficient for making one pound of leather. The duty, which up to 1842 was twenty shillings per ton, was then reduced to five shillings, and entirely removed in 1845. Its price varies from ten to twenty pounds per ton, according to the stock and seasons.

Myrobalans, the dried fruit of various species of *terminalia*, is extensively employed in tanning and dyeing factories. There are several kinds, all of which come, however, from the East Indies, by Calcutta and other ports. This sort of fruit when ripe is pear-shaped, deeply wrinkled, of brownish-yellow hue, and weighing from seventy to one hundred grains. The whole of the astringent matter which it yields is contained in the husk, which is easily separated from the inclosed nut by bruising the whole; besides the tannin, a yellow coloring matter with mucilage and other principles is extracted. The tannin from this source differs but slightly, according to STENHOUSE, from that found in nut-galls.

Divi-divi is an article which has acquired, within a comparatively modern date, an interest with tanners and commercial men. It may be classed with the foregoing, since it consists of the dried pods of a leguminous shrub—*cæsalpina coriaria*—which is indigenous to South America, and grows to the height of twenty and even thirty feet. The pods are about three inches long, of a dark brown color, and curled up as if they had been submitted to a high temperature during desiccation. The whole of the tannin is concentrated in the rind of the pod, immediately beneath the epidermis, and has consequently a very astringent taste, but the inner portion that incloses the seed is very insipid. Besides tannin, it yields coloring matter, and a mucilaginous substance which interferes with its application in dyeing and printing. The leather prepared with divi-divi is very porous, and tinged brown or brownish-red, according to the density of the ooze, time allowed, and state of exposure to the air. Its formation is attributed to a fermentative change induced by some of the extracted matters; this change occurs as well in cold as in warm weather, but more frequently in the latter. During the reaction, a reddish matter deposits upon the leather in course of preparation, and on the sides of the pit. By preventing oxidation of some of the principles present, through the exclusion of atmospheric air, none of the forementioned substance appears, and the leather retains the natural color. A solution, or extract of divi-divi, readily affords a deposit of bloom to leather. STENHOUSE has shown that the tanning matter of divi-divi, though similar to that contained in galls, inasmuch as it exerts a like reaction on solutions of sesquisalts of iron, is, nevertheless, different from the latter, since it produces no pyrogallic acid when submitted to dry distillation.

WOOD.—This material has not been converted to any useful end so far as it immediately concerns tanning, notwithstanding, that tannin, as before stated, exists to some extent in many species.

ROOTS.—Several substances of this nature may be advantageously applied in tanning. The root of the common avens, *geum urbanum*, contains, as shown by TROMSDORFF'S analysis, forty-one per cent of tannin. This plant is perennial, and is indigenous to Europe; it grows wild generally in damp and shady places. The root is about a quarter of an inch in thickness, has long descending fibres, and appears in alternated layers of red and white, the former predominating. It should be gathered in spring, and dried cautiously at an incipient heat. It has a slightly bitter and astringent taste, and, in the dry state, an odor not unlike cloves.

Ratany root is another substance very rich in tannin. MORFIT describes this shrub—*krameria triandria*—as being indigenous to Peru, growing in mountainous districts, and flowering at all seasons. As found in commerce, it is in pieces of irregular shape and size, some not thicker than a pipe-stem, and others an inch in diameter, and two or three feet long. Occasionally, several of the stems issue from one head. The bark is of a dark yellow or brown color, readily separable from the wood, and has an astringent, nauseous, and slightly bitter taste. The woody part has less taste, and a color approaching to red. Water at 212° dissolves the valuable principles, and the decoction, which has a deep-brown color, is abundantly precipitated by the mineral acids. The alkalies only change its color to that of urine. Sulphate of iron produces a black, and acids a fawn-colored precipitate. Gelatin proves the presence of tannin. The following analyses by GMELIN and PESCHIER indicate the composition centesimally:—

	Ratany root.	
	Gmelin	Peschier
Tannin,	38·3	42·6
Gallic acid,	—	0·3
Sweet matter,	6·7	—
Nitrogenous matter,	2·5	—
Mucilage,	8·3	—
Lignin,	43·3	—
Krameric acid,	—	0·4
Gum—extractive and coloring matter,	—	56·0
Loss,	·9	—
	100·0	100·0

TOURNAL has drawn attention to a perennial plant growing wild in the south of France, the dentillaria or leadwort—*plumbago Europæa*—on account of its contents of tannin. The same chemist has made reference to the *statice* or marsh rosemary, and suggested its being employed as a substitute for oak bark. The Kalmucs, it is stated, use a decoction of this plant and sour milk, for tanning the skins of sheep and goats so as to be available for clothing.

BARKS.—This species of tanning material is by far more generally preferred in tanneries than any other, and that which ranks of highest importance for the purpose is oak bark. There are several kinds of this substance, varying more or less in their amount of tannic acid; these, however, come under two classes—the evergreen and deciduous oak barks. Like most of those substances already described, the virtues of the oak and other barks are not disseminated equally in the several parts; indeed, in the rind of the common oak of these countries, there are portions in which no tanning or other valuable secretion is found. In examining the exterior covering of trees generally, a very great analogy will be observed between it and the skin of animals. For instance, the *epidermis* or outer thin, dry, and occasionally transparent layer of matter, has its analogue in that of the skin; and, like the latter, it is thrown off as the tree grows old and increases in size, owing to the formation of internal layers of other matter, which cause the epidermis to fracture and ultimately to fall off. The matter beneath the epidermis is a layer of cellular substance, which partakes more or less of the vitality of the tree. It is generally the seat of the green color, and, like the *rete mucosum* of animals, is being constantly dried up into the epidermis exteriorly, whilst the secretion of herbaceous matter from the interior maintains it in the normal state. Beneath this is found the *cortical* tissue, of which, as the tree grows older, the woody matter is formed. In it are found all the valuable secretions of the tree, such as gum, sugar, resin, oil, and the other matters which are so generally applied in medicine and the arts. It is constituted of a number of elongated cells, divided into layers by a variety of longitudinal woody fibres. This is more particularly the case with the inner portion of this layer, and which is called the *liber* from its organized appearance. It immediately overlays the real ligneous matter, or wood of the tree. In its general construction it resembles in a measure the last-mentioned, only that there are more longitudinal fibres, forming as it were leaves or laminæ, being reticulated and bound together by cellular substance. These layers may be separated by macerating the *liber* in water, which removes the cellulose, so that they appear like the pages of a book, and hence the term *liber* applied to it. It is this portion that is annually converted into wood, and which gives to the transverse section of the heart of the tree the annular appearance it presents, and which is generally termed the *grain*. Each of these rings represents a year's growth of woody fibre.

As regards tannin, the parts of the *cortex*, or true bark, in which it is mostly contained, are the exterior layers of the portion known as the liber, and the interior of the cortical tissue—the inside portions of the former, and the most exterior of the latter, yielding very little of this principle. The same observation is true of other matters, such as quinine and the like. The various dyes are seated frequently in the exterior portion of the cortical tissue. The sap always ascends through the cellulose of the real bark; and as this fluid is the source from which tannin is secreted, it is evident that there will be more of it in the bark, when the flow is greater than at other periods. Experiments have proved this to be the case as regards oak, and the same observation applies to the barks of other trees, such as the willow, elm, pine, birch, beech, *et cetera*, with equal force.

It may be well to state here, as briefly as possible, the nature and peculiarities of the more important barks referred to at page 500, with the view of showing their adaptability for tanning. In this digest, considerable information has been obtained from Professor Morfit's very copious work on tanning and currying leather. The bark of the cinnamon-tree, though yielding tannin, has not yet been employed for the manufacture of leather. Larch and birch barks are resorted to in a very limited way, being in Great Britain and Ireland applied only for tanning bazils and other sheep-skin leather. In the larch-tree bark the tannin amounts to two per cent.; but in that of birch, Davy found 6·75 parts centesimally. Birch bark is very much employed in Russia for making the fancy red-colored leather, known in that country as *jucten*, and other kinds, and the peculiar resisting powers, as well as its odor, are attributed to the assimilation of the oil which this bark contains. The American variety of the chestnut-tree bark yields four per cent. of tanning material, and the leather prepared from it is said to be more flexible than that made with oak bark. The bark of the Spanish chestnut contains, according to Davy, four per cent. of tannin. In the United States, the bark of the hemlock spruce, a species of fir—*abies canadensis*—is much used for tanning as a substitute for oak bark. Morfit states that this tree, which grows to the height of seventy to eighty feet, constitutes three-fourths of the evergreen woods in Nova Scotia, New Brunswick, Maine, Vermont, and part of New Hampshire; it is less common further South, though found in the middle and Southern states on the Alleghanies. The bark of this tree is grey when young, but grows lighter when old, and is generally covered with moss. In June the barking is effected, and before being ground half of the epidermis is shaved off. Leather made with this bark is reddish, and is judged inferior to that yielded by oak bark; however, the two barks worked together are supposed to afford a better product than oak tan produces by itself. Davy found in the bark of the beech about three per cent. of tannin. Some varieties are employed by the tanner when oak bark happens to be scarce, but the leather from it is white and inferior. The same chemist obtained from the bark of the Lombardy poplar, 3·12 per cent.; from ash bark, 3·32; from elm bark, 2·7; from the white or European willow, 2·295; and from the Leicester willow, 6·86 per cent. of tanning principle. Lombardy poplar bark makes a light-brown colored leather, which acquires during the tanning a fragrant odor, somewhat resembling that which is given by birch bark. Elm bark is not much used in these countries for making leather, but it is utilized in this way in Norway, and the remarkable beauty of the glove leather of that country is attributed to the mode of tanning, which is done with elm bark. Willow bark also is restricted to the tanners of Northern Europe, although it is worked up occasionally with oak bark in British and other tan-yards. The Danish and Schoonian leather, much in request for the manufacture of gloves, owing to its peculiar and agreeable smell, is prepared with the bark of the white willow; in Russia, the tanner uses this material occasionally, but impregnates the leather subsequently with the empyreumatic oil of birch bark. The barks of all the cinchona species afford considerable quantities of tannin; still these are more valuable in pharmacy, owing to the alkaloids they yield, and, therefore, they are not resorted to for leather-making. Several other trees afford tannin, when their barks are submitted to the usual process, but they are rarely turned to any account.

Oak Bark.—The bark of the oak, has been for a long period extensively employed in tanning skins, and if other materials have been used, it still happens that, in Great Britain and Ireland at least, these have not been resorted to by preference, but rather from the scarcity of the staple article, oak bark, which seems to part with the tannin under those circumstances which best avail for its combination with the tissue of the skin, and thus for converting the latter into an article of prime quality. There are several varietes of oak, known as well in Europe as in America, all of which secrete tannin in their bark; but those which are valuable to the tanner are the different varieties of *quercus robur*, *quercus coccifera*, and sometimes the *quercus suber*, indigenous to Europe; and the *quercus falcata*, *quercus rubra*, *quercus tinctoria*, and *quercus prinus monticola*, indigenous to the American soil. The bark of the *quercus robur*—which term is applied to designate a group of closely allied species or varieties, and of which the *quercus pedunculata*, and *quercus sessiliflora*, form the two principal—is generally preferred by the tanner, with the exception of Norway and the North of Russia and some districts in France. In Norway, as already remarked, the birch and willow are resorted to, and in Russia and France the bark of other species of oak, the *quercus glomerata*, and *quercus coccifera*, are occasionally substituted. The latter variety, known also as the kermes oak, is a tortuous branching shrub inhabiting the South of France, Portugal, and Spain. It grows to the height of three to four feet in close clumps, the roots interlacing one another, so that the soil, which might otherwise be washed away by the heavy rains, is retained. The bark of the root of this shrub, which is sometimes called coppice oak, is of a yellowish brown hue, and very rich in tannin. It is much in quest in France for tanning sole leather of a superior quality.

Barking of Trees.—In the foregoing pages are given the varied natural products which have been more or less employed, or offer advantages for tanning. The bark of the oak is, however, the most extensively consumed, and, therefore, much care is paid to its collection and harvesting. For a long time it was supposed that the rind of old oaks was more valuable for tanning than the product from younger wood; but experience is rectifying, or has done so, this mistake, for tanners have by a long course of working ascertained with certainty, what, through the labors of Sir Humphrey Davy and others, has long been on record, that the bark of young trees is richer in tanning principle, than that of old ones; and, not only does the bark of the former offer this advantage, but the leather prepared with it is softer and whiter than what old bark produces, owing to the amount of coloring and extractive matter which they yield. Doubtless, the best age at which the trees should be barked, is from eighteen to twenty-five, or thirty years; but owing to the importance of the timber for building and other purposes, rarely are trees of this age felled in England or European countries. In France, however, they harvest the bark of oak of this age, but the wood is not turned to further use, excepting for the manufacture of charcoal, owing to the variety being unadapted for the builder. In France, too, the advantage may be gained of collecting the bark in spring, at a time when the sap is in full flow, and when there is most tannin contained in it; but in other countries, where the bark of the tree constitutes only an inferior secondary product compared with the wood, this season is not chosen, in consequence of the timber being cut when the sap is in active circulation and thus liable to decay. In England, Holland, and America, the period for stripping the bark is about June; but it varies according to the mildness of the winter and the spring. The operation of barking, is performed by cutting two circular bands round the trunk, at a distance of two, three, or more feet, then a longitudinal strip from one band to the other, loosening the bark at the upper, and stripping it off in bands towards the lower end. When stripped, the pieces are spread out to dry in beds, a shady site being preferred, care being taken to turn them occasionally, so as to prevent tho beds heating. If the harvesting of the bark is not strictly attended to, considerable injury is sustained, not only in the loss of tannin, but more so in the kind of leather it affords in the pits. For the most part, or indeed in all cases, the bark should rest on hurdles elevated moro or less from the ground in an inclined state, and the fragments ought never to be heaped together more than from twelve to eighteen inches in thickness. Provision ought to bo made to protect the bark from the rain, and the whole should be turned at least once a week till quite dry. After this it is usually stacked in larger rectangular heaps, and protected by thatch, if not by a roof, from rain or wet.

Quality of Barks.—It is important, that in regard to this article of so much value to the tanner, he should have some means of ascertaining its quality. By physical characters, the man of practice and experience will often form a good opinion in this respect, so as to decide between a good and bad quality of the same kind of bark; but this will not enable him to tell what amount of tannin it contains. Thus, if the bark has a whitish color exteriorly, and a reddish interiorly, and combines with these a dry, fragile, and clean fracture, and an astringent taste, the bark has been well harvested, and other properties being taken for granted, it is of good quality. So also when the epidermis and liber are thick, dry, and ligneous, with large crevices and a blackish aspect, it is deemed of an inferior quality, for the former characteristics indicate age, and the latter, that it has undergone a heating or fermenting change. There are other indications also from which persons acquainted with tanning materials form a judgment as to its goodness; it happens, however, that there are exceptions, so that an article presenting one or more of these appearances, may be of a first-rate quality, and make a good leather; but, under any circumstance, they will not lead the purchaser to the knowledge of the per centage of real tannin they yield. To attain to this end, a determination of the tannin must be made by chemical means, and even then the results are often only approximative.

Estimation of Tannin in Barks, et cetera.—Several methods have been devised for estimating the amount of tannin in barks and other products which are used in tanning, most of which are founded on the behavior of tannic acid with gelatin, and similar bodies; but mention will be made here only of those of Davy, Stephens, and latterly, Warington. The process of Davy consists in treating three hundred and sixty grains of the powdered bark with a pint of boiling water, the vessel being frequently agitated during the digestion, which ought to last twenty-four hours. After filtering off the extract, it should be mixed with an equal volume of solution of jelly or isinglass, prepared by dissolving sixty grains of either of those substances in a pint of hot water. The precipitato of tanno-gelatin is then collected on a tared filter, exsiccated and weighed, and four-tenths of the entire taken as the proportion of tannin contained in it. Modern research has shown, however, that it is almost impossible to separate the precipitate by filtration from the liquid, so that at best this method is tedious; but it is inaccurate, inasmuch as the first portions which fall contain about fifty per cent. of tannin, which diminishes towards the end of the saturation. Sulphate of quinine, acidulated with a few drops of sulphuric acid, may be employed for precipitating the tannin from its solutions completely, and the deposit, unlike the gelatin compound, is constant in its composition. The tanner, however, in his yard, bases his operations on the indications of what is called the *barkometer*—an instrument like a hydrometer—and according to the extent to which it sinks in the extract, so is the strength of the *ooze*, or tan-liquor estimated.

STEPHENS, to avoid the error to which DAVY'S method is liable, proposed to estimate the tan by combining it directly with the cortical tissue, as in tanning, and determine the amount of the acquired weight. For this purpose, strips of the best ox hides, shaved as thinly as possible, are washed in water, thoroughly dried and weighed, then soaked in water a second time till they become soft and porous, and immersed in the extract of the sample of tan under examination, at a temperature of 90°. In the course of eight or ten hours, the whole of the tannin will have combined with the skin, so that after this period, by abstracting the strips, drying and weighing, noting the increase as the amount of tannin in the sample operated upon, the per centage in the bark may be calculated. This mode is likewise tedious, and fails to give satisfactory results.

WARINGTON proposes to estimate the tannin, not only in barks, but in all other astringent substances volumetrically, by determining what volume of a standard solution of gelatin is required to precipitate the tannin from the extract prepared from the sample submitted to examination. In preparing the test solution, the above chemist recommends the long staple isinglass, as that is the most constant in its quality, and the least liable to undergo change. The solution is made of such a density, that a degree on the burette will represent one-tenth or one-fourth of a grain of tannin. Besides the preparation of the test liquor, the only other novelty in the operation, is the method employed for filtering off portions of the menstruum in order to determine whether the whole of the tannin be precipitated. As the passing of the liquor through bibulous paper, would not afford a clear filtrate, a piece of glass tubing, a foot in length, and half an inch in internal diameter, was selected; into the lower extremity a piece of wet sponge was introduced, and when it was desired to abstract a portion of clear liquid from the assay, in order to test if further precipitation took place, the sponge end of the tube was submerged, and the fluid filtered by ascending through the sponge. Part of the clear menstruum thus obtained, was transferred to a test tube, and a drop of the test solution added, till the point of saturation had been accurately arrived at. By this method, which is as applicable to the substances rich in tannin as to bark, accuracy and expedition are secured.

The annexed table, from MORFIT, indicates the per centage of tannic acid contained in the various substances specified :—

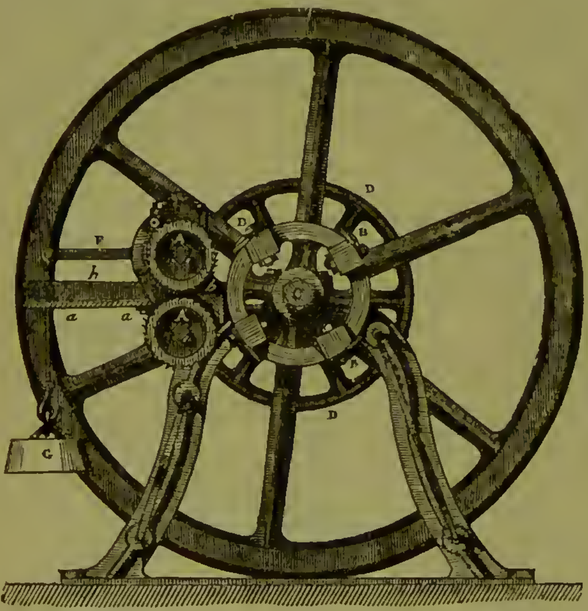
TABLE OF THE AVERAGE QUANTITY OF TANNIN IN DIFFERENT SUBSTANCES.

Substance.	Per centage of tannin	Authority.
Catechu—Bombay,	55·0	Davy.
" —Bengal,	44·0	"
Ratany root,	42·6	Peschier.
"	38·3	C. G. Gmelin.
Kino—tannin and extractive,	75·0	Vauquelin.
Butea gum,	73·2	E. Solly.
Nut-galls—Aleppo,	65·0	Guibort.
" —Chinese,	69·0	Bley
" —Istrian,	24·0	Roder.
Old oak—white inner bark,	21·0	Cadet de Gassincourt.
" " "	14·2	Davy.
Young oak— " "	15·2	"
" —colored or middle bark,	4·0	"
" —entire bark,	6·0	Davy and Geiger.
" —spring-cut bark,	22·0	" "
Oak kermes—bark of the root,	8·9	" "
Terra japonica, or gambir,	40·0	Esenbeck.
Avens root—*geum urbanum*,	41·0	Tromsdorff.
Squill—bulb,	24·0	Vogel.
Statice of South Carolina,	12·4	Parrish.
Birch bark,	1·6	Davy.
"	1·4	Biggers.
Beech bark,	2·0	Davy.
Larch bark,	1·6	"
Hazel bark,	3·0	"
Chestnut, American rose,	8·0	Cadet de Gassincourt.
" Carolina,	6·0	" "
" French,	4·0	Julia de Fontenelle.
" Spanish—white inner bark,	1·3	Davy.
" " —colored, or middle bark,	0·3	"
" " —entire bark,	0·5	"
" horse,	2·0	Julia de Fontenelle.
Lombardy poplar,	3·5	" "
Blackthorn,	3·3	Davy.
Ash bark,	3·3	"
Sassafras—bark of the root,	58·0	Reinsch.
Elm bark,	2·9	Davy.
Sumac, Sicily,	16·2	"
" Malaga,	16·4	"
" "	10·4	Franck.
" Carolina,	5·	Cadet de Gassincourt.
" Virginia,	10·0	" "
Willow, Leicester—white inner bark,	16·0	Davy.
" " —colored, or middle bark,	3·0	"
" " —entire bark,	6·8	"
" " —bark of the trunk,	1·4	Biggers.

Substance.	Per centage of tannin.	Authority.
Willow, weeping,	16·0	Cadet de Gassincourt.
Sycamore bark,	16·0	" "
" "	1·4	Biggers.
Elder,	2·3	Davy.
Plum-tree,	1·6	Biggers.
Cherry-tree,	24·0	Cadet de Gassincourt.
" Cornish,	19·0	" "
Tormentil root,	46·0	" "
Cornus sanguinea of Canada,	44·0	" "
Alder bark,	36·0	" "
Apricot,	32·0	" "
Pomegranate,	32·0	" "
Bohemian olive,	14·0	" "
Tan shrub with myrtle leaves, bark of,	13·0	" "
Service-tree bare—June berry,	18·0	" "
Cloves,	15·0	Davy.
Winter's bark,	9·0	Henry.

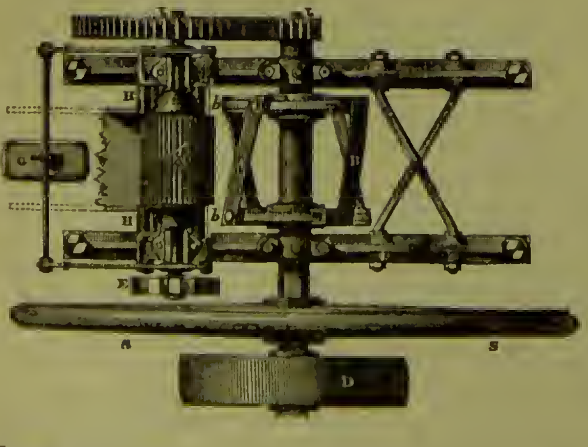
To render any of the foregoing materials suitable for the present operations of the tanner, it is necessary to bring them into a minute state of division, in order that by the treatment to which they are subjected, they may the more quickly yield up their tannin.

Fig. 342.



With the exception of the inspissated juices, this condition is gained by grinding or cutting machines which reduce the roots, branches, or barks, to a fine powder.

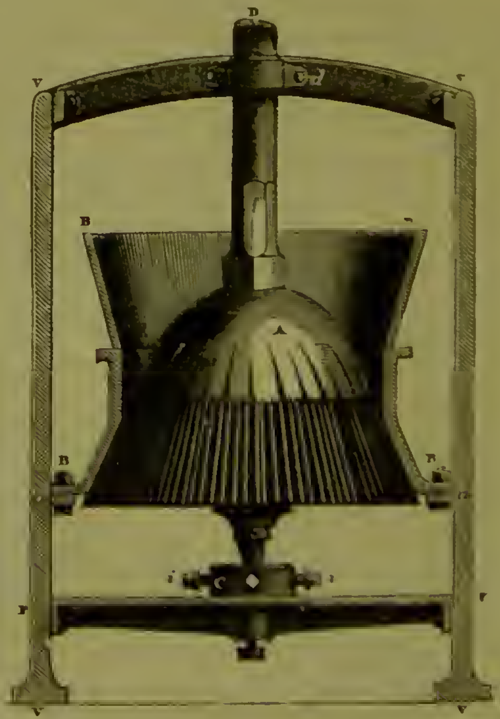
Fig. 343.



Numerous kinds of mechanical adaptations have been introduced into this department, varying in simplicity from the old head-stone rollers, to very intricate arrangements. It would require too much space to give even a curt description of these; suffice it then that the principles on which they are constructed may be inferred from the machines described here :—

FARCOT'S bark-cutting machine, extensively used in France, is shown in elevated section and plan in Figs. 342 and 343, in which A A′ are two fluted cylinders, which supply the bark previously spread upon the table, *a*, having a raised ledge, *h*, to the cutting apparatus. This is composed of two parallel circles, fixed upon a common axis, C, having steel plates or knives, B B, screwed upon them, and which are disposed in the form of a helice or spiral. On one end of the axis, C, is the fly-wheel, S, and drum, D, which receives the movement or power by a strap that connects it with the main shaft of the engine; the other end has a pinion, I, which gears into a toothed wheel, J, on the axis of the fluted cylinder, A, and by means of another smaller one acting upon E, on the axis of A, the motion is likewise transmitted to the latter. By the levers, F F, and a weight, G, the two cylinders, A A′, are regulated to any required proximity. Inside the fluted cylinders is a longitudinal piece of steel, C, which delivers the bark to the revolving knives, and at the

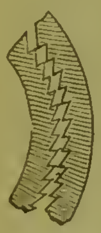
Fig. 344.



same time acts by its sharp edge as a shears towards the cutting knives. The cylinder which carries the cutting knives makes about one hundred and thirty revolutions per minute, as also the feeding cylinders; and the quantity of bark cut averages one thousand six hundred pounds per hour.

The chopped bark is then passed to a mill for reducing it still further, and which is shown in Fig. 344. This machine is on the principle of Weldon's bark-grinding mill, introduced so far back as 1797. In this figure, A is a conical drum of iron on the end of the shaft, D, which forms its axis, inclosed in the cast-iron hopper, B B, where the coarse bark is deposited. This hopper is firmly secured by screws to a flange, which runs all round the framework, *v v*, as shown at *a a*. In the top of the exterior is a cross beam secured by screws, and having a socket in the middle part through which the axis of the drum passes. The lower part of this shaft rests and turns upon a bed, C, upon the stage, T, and regulated so as to have the cone, A, in position, by the side and bottom screws, *a′a′* and *b*. The inner face of the hopper, B, which is in close contact with the revolving cone, is, like the latter, serrated or grooved, so that the bark passing down is more minutely sundered. Fig. 345 shows the position of the two cutting surfaces with respect to one another.

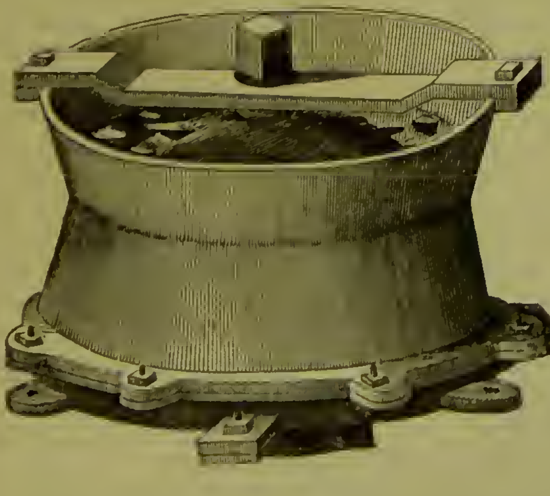
Fig. 345.



The central drum makes twenty-five revolutions per minute, and in the course of twenty-four hours grinds about eight thousand six hundred pounds of bark. The cutting machine already described is capable of supplying three grinding mills.

Another grinding mill, very much used in America, where it is known as Wiltze's or Catskill's, is shown in Fig. 346. This in principle is the same as Weldon's, only that instead of grooves an arrangement of sharp-edged teeth, both in the inclosed bell and hopper, is employed. As the bell turns by the power exercised upon the shaft, the teeth in the former, revolving, also react on the principle of the shears with those in the interior of the case, and the bark is very finely and rapidly reduced. Before the matter is submitted to this machine, it is broken by passing it into another hopper adjacent to the former, in which there is a sharp-toothed hoop or curb, and which divides the bark into pieces. It is moved at the rate of thirty to forty revolutions per minute, whilst the grinding machine may travel at the rate of one hundred and fifty. With this speed, communicated by a ten horse-power engine, it will grind from one to two cords per hour. The bark is cut short, without being reduced to flour, and thus it is more readily exhausted; there is also the additional advantage that, should the bark be moist, it does not become clogged like others.

Fig. 346.



The Skins or Hides.—The next object of attention in the preparation of leather, is the hides or skins of the animals. Three classes are specified in commerce; the term *hide* is applied to the skin of the larger and full-grown beasts; *kips* are the skins of the younger animals of the same class; and *skin* indicates the hides of the sheep, goat, kid, and the like. The term *kip* is qualified by the size of the skins. Generally speaking, the skins which are converted into leather, are those of oxen, cows, and calves, of the sheep, the goat and their young, of the horse, the pig, the dog, and a few others; but by far the most extensively worked, as well as the more important, are ox, cow, and horse hides, kips, calf, and seal skins. Considerable difference is observed in the thickness and quality of the skins of various animals, even of those of the same class, owing to circumstances connected with the food, age, variety of breed, the state of health, and even the period of the year when they are slaughtered. Thus, large oxen are well known to afford hides which are tanned into thicker and heavier leather than bulls or cows, especially if the latter be old, and have had several calves. Bull hides are coarser grained, and thinner in the back than those of oxen and heifers, or young cows, but much denser in the neck, and parts of the belly. It would also appear that when cows have repeatedly calved, the skin becomes distended and thinner, and does not, therefore, afford as heavy a sole leather as that of younger beasts. Again, hides of animals dying in a state of disease, are found to be much inferior to those of healthy ones of the same class, although the apparent difference is not very marked before tanning. No very definite *criteria* are known, to guide the purchaser in distinguishing the quality of hides and skins. If the hide be thin, flabby, soft, and will not bear handling, then such a one will not make good leather; but should it present the opposite qualities, it may be confidently expected to be a good article. It has been remarked of sheep, that the finer-wooled variety have inferior skins; also that the skin gains in thickness and quality, considerably, in the course of a few days after shearing.

Ox Hides.—Under this head may be enumerated the skins of *oxen*, *cows*, *buffaloes*, and *calves*. In Great Britain and Ireland, the market draws, in the first place, upon the home produce; these are usually vended in the *green* or fresh state. They are obtained from the extensive *abattoirs* generally found in large towns, and local butchers throughout the country. But besides these, considerable numbers are imported from other countries, especially from South America, the East and West Indies, and the Cape of Good Hope. The trade carried on between Great Britain and the South American ports in hides, though averaging a million annually, is only a fraction of what sprung up of late years between that country and other European nations, such as France, Belgium, Austria, and Greece. The animals which roam along the Pampas and Llanos, or great plains, in herds of vast numbers, are, in addition to those owned by the extensive cattle owners or *hateros*, the stock whence this vast quantity is annually derived. They are imported in the dry state, and salted, and produce a very good sole leather. It should be remarked, however, that the hides from beasts inhabiting the extreme Southern latitudes, are not suited for tanning so well as those from the temperate and Northern parts of the globe. The *green* or fresh hides of the home market always rate higher than other sorts, owing, perhaps, to the fact that they do not require so much labor as the imported dry kinds; still, in consequence of the amount of water they contain, they prove to be much dearer than the others; for allowing that for the production of one hundred pounds of leather, seventy-five pounds of dry hide are requisite, the equivalent of this of salted hides, would average a hundred and fifty pounds, and a hundred and eighty-five of green or market hides. Heavy hides are converted into sole, belt, and harness leather, also for carriage coverings, and the smaller and lighter kinds are made into leather much used for *skirtings*, and for enamelling. That which is used for ladies' shoes, and for bridle-leather, undergoes a bleaching process, termed *fair finish*. Hides from the West coast of Africa, make good upper leather, but are much employed in their raw state for trunk covering.

Calves' skins and *kips* of home produce are of very superior quality, and produce a leather, when made with good oak bark, very extensively worked into uppers of shoes and boot fronts. In France, where the calf-skin leather has been reputed for its excellence, they are taken off the animals when five or six months old. Kips are imported from the East Indies, Buenos Ayres, and Monte Video; those from the former place are dried and salted, or merely exsiccated, and from the latter places, they come simply salted. The countries adjoining the Baltic, more especially St. Petersburg, send here a good many; but owing to the animals being slaughtered when young, they are, properly speaking, skins. Many of them, however, as well as some imported from other countries, belonged to small, but full-grown animals, and are, properly speaking, hides. The lesser and inferior kinds of kips and calf-skins are tanned for bookbinders' use, for gloves, and the manufacture of ladies' boots and shoes. Buffalo hides imported from the East Indies, are tanned like ox hides, but they make an inferior quality of sole leather. The American Indians prepare these into robes, the hair being retained on them. When tanned in a particular way with oil, they constitute what is termed *buff belt*-leather, which is superior to the similar article made of cow-hides.

Horse Hides.—The skins of these most useful animals are much inferior to those of oxen in thickness, texture, and strength, and, consequently, they are never prepared with the view of making *sole* leather, though the better quality is used when tanned for uppers. The chief consumption is, however, as cordovan, or enamelled leather, the hides being split by machinery to reduce them to the adapted thinness. Horse hides are likewise made into tawed, white, or alum leather, and are in this state used as aprons for certain classes of mechanics, and as thongs for the manufacture of the commoner kinds of whips, and for sewing common harness. A considerable number of horse hides is annually imported from South America, sometimes as many as one hundred and ninety or two hundred thousand. The imported hides are much superior to those which find their way to the home market, on account of the latter belonging generally to old and worn-out animals. while the former have been flayed from the captured wild horses of the pampas, lying between the chains of the Andes. Ass and mule hides, tanned and so prepared, serve for the manufacture of scabbards; the leather is called *shagreen* or *shagri*.

Sheep Skins.—The home supply is very extensive; and although they are capable of making only a spongy weak leather, the uses to which they are devoted are various, and their manufacture gives employment to numerous hands. Tanned with bark they constitute bazils, and are used for making slippers, and as bellows-leather; but when prepared with alum and salt, or with oil, white leather, much employed for aprons and by druggists, chamois leather result. A good many are split, the upper or grain side being tanned with sumac and dyed, then worked up as *skiver*, *roan*, and *morocco*, into pocket-books, hat-linings, and the under portion being made into white leather, and used very much by the chemist; but it is much the more general practice to reserve lamb skins for the latter purpose. Sheep skins are sometimes tanned with the wool adhering to them, and made into mats. The principal seats for the dressing and dyeing of sheep skins in England, are Bermondsey, Leeds, and Manchester; from these places they are exported to various parts of Germany, South America, and the United States; but the exports to the latter country are only partially prepared and salted. A large number of the skins of a particular breed of sheep is imported into Great Britain, and a similar variety is brought into this country, and likewise into France, from Asia Minor. In the latter country a considerable trade rises from the preparation of lamb skins for ladies'-glove leather, for linings of morning gowns, for slippers, and for winter gloves. In the hides from Asia Minor the wool is kept for the purpose of retaining the warmth. Considerable difference may be observed in the quality of lamb skins; those from the animals killed shortly after being born are possessed of a very fine grain. and take a very uniform dye; the same qualities are, in a great measure, retained by the skins till a month old, but from this period they begin to deteriorate. In the Southern parts of France and in Italy great numbers of lambs are killed, averaging four weeks old, and the leather prepared and employed as a substitute for kid leather. Not less than one million four hundred thousand of these skins are annually imported to Great Britain for the use of the glover.

Goat Skins.—A very large trade is carried on in Great Britain and Ireland in goat skins, and the tanned and prepared leather they yield. In the latter country a number of native skins is used, but the British market is supplied almost entirely by imported goods, more especially from Switzerland and the valley of the Rhine, from Magadore, the Cape, and the East Indies. Those from Switzerland—Swiss skins—are more esteemed, because they possess a close, fine, and equal grain, which enables the dyer to give them a brilliant and permanent hue; the leather is also stronger, and wears better than any other manufactured from goat skins. On an average about one hundred thousand are imported annually, and fabricated into morocco for the demands of the various branches of trade. Mogadore skins are made into a kind of black morocco leather, which still goes by the title of Spanish leather or cordovan, in consequence of the first supplies of this article being obtained from Spain and the Cordova, where the Moors originally brought the manufacture to great perfection. The sound skins which arrive from the Cape of Good Hope are much larger, and superior in strength and thickness, to any other variety. East India skins are small and light, and are generally converted into leather chiefly used for ladies' shoes and upholstery. Those from Mexico, known in the American market as *Tampico* skins, bear a very high character. Compared with sheep skins, those of goats are much superior in texture, strength, and durability. Goat skins are occasoinally prepared so as to imitate chamois leather, and applied to most purposes to which the latter is adapted, and likewise with the hair on, and used for matting. Kid skins, manufactured into leather, are most extensively consumed by the glover, also for shoes, binding leather, and the like. Great numbers are produced in Ireland, the South of France, Switzerland, Italy, and other European countries. Those of France have the greatest repute; the Irish skins are likewise highly esteemed. After the animal begins to feed upon herbage, the skin invariably loses in delicacy of texture, and, therefore, becomes unsuited for the finest gloves.

Deer Skins.—A considerable number of these skins is manufactured into chamois leather, particularly in the United States, and also into glove leather. The preparation of this kind of leather in Great Britain and Ireland is very limited.

Hog or Pig Skins.—In Scotland, the swine are skinned; the skins are tanned, and constitute a very porous, light, but nevertheless very tough and durable leather. It is largely used by harness-makers and for saddle seats. The practice of skinning pigs is followed on the Continent, where the hide is dressed with the hair on, and used to cover portmanteaus, knapsacks, *et cetera.*

Seal Skins.—Of these a great quantity is imported yearly into Great Britain, and manufactured into upper and varnished leather. They are obtained from the animals captured along the shores of North America, from Newfoundland to the Arctic ocean, for their oil. A large portion of the supply comes from the coast of Norway. The skin of the seal is light, but of a close texture, and, when properly tanned, yields a leather which has greater strength, in proportion to its weight, than any other variety. Seal skin is usually made into black enamelled leather for ladies' shoes, the stronger sorts being employed for the upper part of hunting and riding boots, and knapsacks. Many skins are merely dressed and converted into materials for caps and fur clothing.

Porpoise Skins.—The skins of the white porpoise have been tanned in Canada, and the leather is said to be soft, strong, and possessed of a beautiful finish.

Hippopotamus Hides.—About one hundred of these skins are annually imported from the South of Africa, and are tanned with oak. The hide, originally of great thickness, assumes the appearance of boards after being tanned. The only use which appears to be made of them, are implements used for beetling in washing and bleaching cotton and linen goods.

PREPARATION OF THE HIDES.—The tanner, previous to submitting the hides, skins, or kips, to the true tanning process, is under the necessity of subjecting them to one or more preliminary operations, with the view of removing dirt, particles of flesh, and in most cases the hair and epidermis; and the manner in which these are effected is of great importance, as much of the success of the subsequent process, and, consequently, of the quality of the leather, depends upon it.

Cleansing.—The hides which have been recently taken from the carcass of the animal require but very little labor to purify them from any filth which may remain attached to them, unless, indeed, as is said to be sometimes the case, they are wantonly saturated with such matters in order that they may weigh heavier. Sometimes, however, such *green* or *fresh* hides, as they are called, when they cannot be immediately disposed of to the tanner, or when the latter does not intend to submit them at once to the processes by which they may be made into leather, are salted to prevent putrefaction. When the hide has to remain for a period of a week, four or five pounds of coarse salt are used to preserve it; if a month, double this quantity is deemed requisite. Foreign hides—such as those from South America—receive more than the above quantity; in some instances as much as twenty pounds of salt per hide are used, according to their size and the season, but the average for foreign hides is about fifteen. All these matters must be separated by steeping and washing; and hence one of the absolute requirements of a tannery is a profusion of water. Green hides are steeped in water during a period of one to twelve hours, according to the quantity of blood and dirt they hold, at the end of which time they must be thoroughly rinsed before removal. In many cases much greater pains must be taken, such as repeated scrapings of the hide with a blunt tool on the beam or support, trampings in the water buckings, *et cetera.* If a current of water is available, much labor is spared by fastening the hides to a rack fixed in the face of the stream, for the friction of the water will detach the impurities without the aid of much mechanical labor. When dried hides, or such as are salted and dried, are treated, the difficulties are much greater, since a longer period and more time is required to soften and bring them into the condition of fresh ones. With these the soakings, trampings with the feet, handlings—that is, the removal from the water or steep—and scrapings are multiplied before they attain the softness and purity of clean fresh ones. In large establishments the mechanical labor required is executed by a kind of mill, similar to that for fulling cloth, wherein the hides are exposed to the continued action of two heavy stocks, which squeeze out the slimy matter and dirt that might induce a putrefactive fermentation. The immersion and handling even in this case require to be alternated with the action of the machine; and it is necessary to remark that where vats or tanks are used, the water should be frequently renewed, otherwise, if the contents happen to get stale or overcharged with the slimy extract from the hides, and the time of submersion be prolonged, there is danger of putrefaction, and, therefore, of injury to the skins. Where only water is employed for the above purpose, it is necessary to keep in view the quality of this liquid, irrespective of the change which it undergoes by saturation with the nitrogenous matters, dirt, *et cetera*, from the hides. When very calcareous, its cleansing qualities are less effective than when the water is *soft;* but, independently of this, it is believed that *hard* water affects the hides in another way, by which their softness and porosity are injured, owing to the fatty and other matters which may be in an incipient state of decomposition, forming combinations with the earthy bases which fix themselves in the skin.

In many parts of France and Belgium, they employ a weak solution of lime to assist in cleansing and freshening the hides, with the view, at the same time, of rendering the succeeding operations of depilation and tanning more easy and efficacious.

Depilation.—After the thorough softening and cleansing of the hides, they are next submitted to a further immersion in baths or tanks with compounds which effect the solution of the cellular matter in which the hair is rooted, or are otherwise exposed to the action of agents which operate towards the same end. A variety of methods are practised by tanners for the solution or softening of the matter which binds the epidermis and hair to the true cutis, or that portion of the skin that enters into the formation of leather, with the view to their removal. The most important of these are the *lime* process, the *sweating* or *fermentative process*, the *rhusma* and gas lime processes; and latterly, in America, the *cold sweating* mode has been introduced with success.

By Liming.—Of these processes the *liming* is by far the oldest, and is still very extensively adopted, but with greater caution than in former times. In its action it is not so quick as certain other agents, necessitates much future labor, and frequently is the cause of injury to the leather; still, probably from its cheapness and the effect of custom, it is more resorted to than any other. Generally speaking, it is now used in the form of a semi-liquid or milk, formed by agitating a certain quantity of it with a given body of water—about eight bushels to one hundred and fifty gallons. The liming is carried on in a series of pits or tanks, sunk in the floor of the liming house; these are built of bricks or masonry, and well cemented, and have an outlet at the bottom for the purpose of drawing off the fluid contents when necessary. Their dimensions vary according to the requirements of the establishment, and the number of skins to be operated upon at once. In some parts, as in France and Belgium, well bound wooden tubs are preferred. The number of these varies from five to twelve, and the solution in them is so arranged, that there is a regular increasing gradation of density from the first to the last, even where the larger number is taken advantage of. The first of these, called usually the *dead* vat, contains very little caustic lime, and this is the one to which the hides after washing are exposed, in commencing the operation. Here they remain for one, two, or three days, according to circumstances, and during this period they receive a handling at regular intervals, some twice, and others three times a-day. This handling merely consists in taking the skins out of the pit or tub, and laying them on a plank or inclined board near the tank, and introducing them again. Before the re-introduction, the contents of the tank are well agitated, with a view to distribute any undissolved quick-lime through the liquid, so that there be no partial or undue effect exercised on the skins. The workmen likewise contrive to spread out the latter in the vat as much as possible, and so every part has the same exposure to the lime. In the dead vat, however, there is left very little if any quick-lime undissolved. After spending the allotted time in the first vat, they are transferred to the second, which contains a stronger liquid, or more lime, and left in this, with occasional overhauling, for a few days, after which they are put into the third, and so on till the hides ultimately arrive at the last vat, which contains the fresh lime. In operating in this rotation the dead vat of one batch of hides becomes the *live* one of the next, and so on in succession. The time which skins take for thorough liming, varies according to their weight and texture. Thus the lighter skins, as of the sheep, are sufficiently acted upon in three to five days, but ox hides, kips, and calf-skins, require two to three weeks, according to the season. Formerly the process of depilation extended over a period of three to fifteen months, and even eighteen, the hides being steeped in the weak lime vats a considerable part of this time, but such procedure is now entirely relinquished. In many parts of the Continent, however, the operations preparatory and conducive to the depilation last two and three months; but in these cases the skins are partly swelled, so that, for this special treatment, they do not require so much attention in the succeeding stages. The quantity of lime which is used by the different tanners is somewhat various, and dependent upon the size of the hides, but the average is from eighteen to twenty-four gallons of freshly-burned fat lime—three to four cubic feet measure—for a hundred hides of average size. The lime is permitted to slack in the strong or live vat, and afterwards stirred about with a wooden spatula, to distribute it equally in the liquid.

When the epidermis is sufficiently softened it is detached, together with the hair on the *beam*. This is an arched wooden or stone bench—Fig. 347—upon which the hide is laid, with the flesh side inwards, and the hair removed by the *scraping knife*, shown in Fig. 348. After the separation of the hair and epidermis, the loose fragments of skin are pared off, as likewise the flesh and fatty matters adhering to the reverse side—such fleshings being economized in the preparation of glue. The implement used for the latter purpose is a long, straight knife, having a sharp edge. This is called the *fleshing knife*, and is represented in Fig. 349. After the last operation, it is necessary to submit the hides to thorough rinsing in the stream or vats, in order to remove all uncleanness, lime, *et cetera*, as much as possible. It often happens that the hides present inequalities as to thickness and the like, and to reduce them to average homogeneity, they are treated with the smoothing or polishing stone, represented in Fig. 350. This tool is of sandstone, interiorly moulded, so as to lie parallel upon the beam, fixed to a piece of wood, and furnished with handles, with which the hide is rubbed, to bring the part to an equal thickness as nearly as possible. This operation is not so much practised by English as by continental tanners. By repeated scrapings in this way with the knives and stone, alternated with steepings and washings, the dirt, hair, fleshy parts, and lime are removed as effectually as possible, previous to the true tanning operation. In the large English tanneries the scraping and fleshing of the hides are executed by mechanical contrivances, and so the manual labour is greatly diminished. Machines for this and other purposes have been constructed by several, among others by POOLE, PLANT, and WOODWORTH.

Fig. 347.

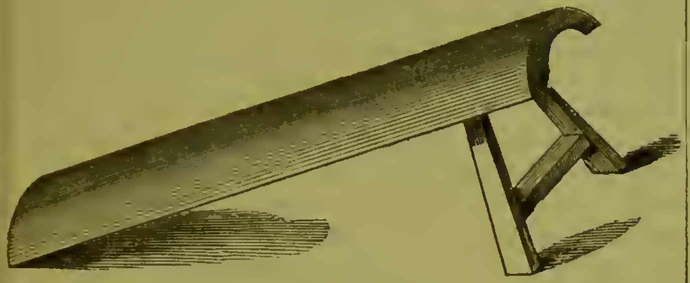


Fig. 348.

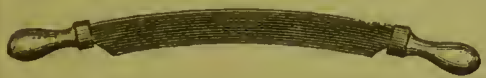


Fig. 349.

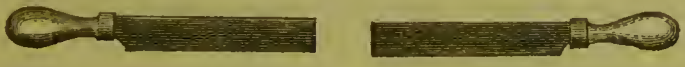
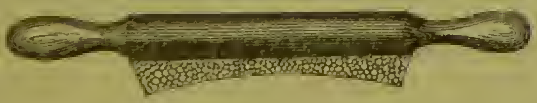


Fig. 350.



Bating.—With respect to the removal of lime from the skin, it has been found that no amount of scraping and rinsing is capable of making a perfect separation, a portion of the earth being retained in the pores of the skin, combined with, perhaps, some of the decomposing tissue, and with the grease and fat of the hide, as a lime soap. These combinations, if not altered and removed, obstruct the union of the tannic acid with the gelatinous fibre of the skin, and not only this, but they communicate a rigidity to the leather which excludes it from such applications as require a soft, tough, and pliable material. Several plans are employed to remedy this defect. The old method is that which is known as the *bate*, or *grainer*, that is, a menstruum prepared by macerating the excrements of pigeons, pen-fowls, and of dogs, in water, and immersing the scraped and clean skins in it for a certain period, when, it is stated, the lime is separated by a chemical decomposition that takes place and renders it soluble. The proportions employed are from ten to twelve gallons of the fresh dung to one hundred, or less if they be large skins; and the time of steeping stretches over ten days in ordinary weather, but less time is required if the liquid be warmer. In this treatment, likewise, the repeated handling and scraping on the beam are resorted to. Investigation has shown that the above matters contain an ammoniacal chloride that parts with its chlorine on coming in contact with the lime, and so gives rise to a soluble combination of this base—chloride of calcium—that may be readily abstracted by water. That this disgusting method should still continue to be so extensively practised is disgraceful to modern science. It is stated, that in London alone not less than five thousand pounds are annually expended in collecting and purchasing the above materials, for the sole use of the tanners of the capital and its suburbs.

Although this method of *bating* the hides is tolerably effective, yet it is well known to be attended with serious disadvantages, not the least of which is the putrefaction of the bate that is going on during the steeping, and which injures the hides by acting upon the tissue of the skin, reducing its weight in the first instance, and in the second, rendering it incapable of yielding the quality of leather it would doubtless produce, did the above change not occur. Taking the hint from the action of the alkaline chloride in this case, some tanners have attempted to prevent the putrefraction induced by the bating with excrements by avoiding its use altogether, using hydrochloric acid in a diluted state as a substitute. The innovation has not yet become very general in England, although many tanners, especially in Paris, are reported to have practised it successfully, the object of the expulsion of the lime being satisfactorily gained by it, and in addition to this, the swelling of the hides also. Sulphuric acid has likewise been proposed as a substitute for the bate, but the effect of this is not so powerful as that of the acid already mentioned, since it constitutes with the lime a very insoluble compound. The acid is, however, almost always resorted to for *raising* or swelling the skins, preparatory to submitting them to the tan-pits. MACBRIDE in 1774 was the first who showed that it possessed this property. TURNBULL introduced the use of saccharine liquids for removing the last portions of lime from the hides, as well as for softening the hair and cuticle. Four or five pounds of coarse sugar or treacle dissolved in sixty to seventy gallons of water, constitute the bath. The sugar in this process forms a soluble saccharate of lime, which is removed by soaking and rinsings. A new process, in connection with others, for the purpose of facilitating tanning and improving the leather, was patented in 1841 by Warington. It consists in employing carbonate of ammonia instead of the usual bate for the graining of the skins; but although this salt converts the lime into a neutral compound, it does not remove it, and consequently, the flexibility and softness of the skin must suffer.

Depilation by Acids.—Besides these methods, by which the influence of the lime on the skin is counteracted, others are employed which dispense with it in the first instance. Acid liquors have long been known to operate upon the roots of the hair and epidermis, so as to detach them from the skin. The Calmuck-Tartars employed a bath of sour-milk for this purpose, and in Paris the same agent is adopted at the present time. Another menstruum, obtained by the fermentation of barley or rye meal, was once very extensively used as a steep for the hides for separating the hair. Here, together with the fermentation, the active body was acetic acid resulting from the latter. This, in common with other acids, such as sulphuric, hydrochloric, oxalic, *et cetera*, operate so as to soften the epidermis and hair, to an extent sufficient to enable the scraping process to cleanse the skin from them. Tanners urge, however, that by their use the skins are swelled to such an undue extent, as almost to render it impossible to prepare good compact leather from them. The weak vegetal acids, however, are not excluded from practice, more especially in France, Belgium, and parts of Germany. Many of the Paris tanners submit the hides, after they have been soaked in water, washed, and fleshed, to a number of acid vats, in a way analogous to the liming. Generally, the series of baths consists of five, which from the first to the last increase in power and efficacy; the first is usually intended to cleanse the hides, the second to soften the hair and epidermis for the depilation, and the other three to swell and give body to the skins. This operation, which is called the *white dressing*, requires a period of five weeks in the summer, and six in the winter season. The quantity of farinaceous matter which is taken varies at different establishments; in some cases one hundred and forty-five pounds of barley-meal, and in others, one hundred and fifty or sixty are employed. The dressing is generally made by leavening one-tenth or one-fifteenth of the bulk till it becomes sufficiently sour; it is then softened with hot water, and after the whole has become a thick homogeneous fluid, free from lumps, it is added to the remaining quantity of the meal in the vat, and tepid water in sufficient quantity poured in to fill the vessel. In some cases yeast is added to quicken the fermentation. Eight or nine hides are worked in each vat, and as in the lime process, the weak or first vat passes in succession from one to the other in rotation. The final vat is composed with sixty pounds of meal leavened and thinned with water, and left to develope acetic acid for fifteen days. In all of these operations the handling and working the hides on the beam at regular intervals are indispensable.

By Sweating.—The depilation is effected at the present day by many English and continental tanners, more especially the latter, by what is known as the *sweating process*. Various means are adopted, but the principle common to all is the softening of the epidermis, by fermentation, or putrefaction. In Paris and other parts of France, one-half the hide is sprinkled with some chloride of sodium, and the other half lapped over it, with the view of arresting the effect of the putrefaction which succeeds from injuring the tissue of the skin. Several hides are then piled one upon another in a pit or other convenient place, and left till an incipient odor of ammonia is observed. This is a sign that putrefaction has commenced, and, therefore, that the hides are approaching to a state in which they readily part with the hair. As the fermentation thus excited would be very deleterious to the leather-making portion of the hide, too great caution cannot be exercised in order to arrest the action as soon as the hair is softened. With this view, the hides should be examined once or twice a day, refolded and piled again, till it is discovered that the hair will readily yield. The same result is attained, without the precaution of adding salt, in Germany and some parts of Great Britain, by simply piling the hides upon one another in a pit. The moisture and circulation of the air acting upon the nitrogenous matters—blood, sweat, and other impurities—readily augment the heat of the whole mass; and incipient putrefaction, recognizable by the evolution of ammonia, follows. It is necessary to examine the hides frequently, lest the action should prove injurious. In many instances they are piled between layers of stable dung in a heap, and the whole covered with the same material, till the hair becomes detached, care being taken, however, to examine the hides every twenty-four hours or less.

Steam and heated vapors have also been tried as agents for removing the hair from the skin. M. Dellut was the first to suggest the use of steam, and his method was carried into effect in several French tanneries. The hides are suspended in an airtight chamber of suitable dimensions, and which is furnished with a perforated, false, or second flooring. Steam is introduced beneath the perforated flooring, and ascends among the hides, through the small orifices, so as to keep the interior of the chamber at 68° to 80°, but not beyond this; for, in the event of the temperature becoming elevated, the gelatinous matter of the skins would more or less enter into solution with the condensed steam on them, and consequently, would afford a less weighty leather. When due attention has been paid to the operation, the hair and epidermis becomes sufficiently softened in twenty-four hours to be removed with the hairing knife. Compared with the putrefactive sweating process, this method is a decided improvement, as the liability to injury is very much diminished.

By Cold Sweating.—In America, especially in New York, New Hampshire, and in many parts of the Northern division of Pennsylvania, a process is in general use, called the *cold sweating*, by which the hair can be removed, and a yield of leather estimated at seventy to eighty per cent. acquired; whilst, by other means employed, such as by steam and lime depilation, not more than thirty to forty per cent. of the dry hides are retained as leather. Besides this very material gain, another advantage follows, namely, that the laborious cleansing and fulling required in the other modes, is unnecessary; and consequently, the hides retain their natural density, a condition which very much improves the quality of the leather. The operations by which this is effected, are thus stated in a foreign journal:—

First, a vault should be prepared for the reception of the hides; this, for convenience sake, should be twelve feet long, the same in depth, and ten feet wide. The walls may be of stone, brick, or a planked frame. There should be one alley or vestibule for entrance, not less than six feet long, having a door at each end, the outer being made double and filled in with tan, to prevent the communication of warm dry air from without. A ventiduct made of plank, ten or twelve inches square, should extend from the bottom of the vault to the distance of three or four rods, and should be fixed not less than three or four feet below the surface of the ground. This channel serves both as a drain for discharging the water of the vault, and for admitting cold damp air to supply the place of that which has become rarified, so that a current is thus kept up through the ventilator at the top of the vault. The ridge of the roof may be on a level with the ground, and on it, extending its whole length, are set up edgeways two planks two inches apart. The space between these is to be left open, but the remainder of the roof may be covered with earth to the depth of a yard. Such covering is intended to preserve a low temperature in the pit, so that the hides may unhair without tainting. Spring water should be conducted, either in pipes or logs, around the angles formed by the ceiling with the walls of the vault; and from these conduits the fluid should be allowed to flow in minute jets, so as to form a spray, or else to raise a mist or vapor, so as to saturate the atmosphere of the vault with watery vapor. This arrangement keeps the temperature of the vault much under that of spring water itself, which usually stands at 50°, owing to the heat rendered latent by the evaporation. Three bars furnished with iron hooks, at intervals of three inches, are laid longitudinally and equidistant near the ceiling, and upon them the hides are suspended. Before hanging up the hides, they are soaked as for breaking, and then suspended from the butts in a way that they remain fully open. In the course of a few days, when the hair begins to loosen on the upper parts, they are taken down, and the middle bar being raised, they are again suspended by the other end, and left so till the hair easily separates. The hides should not be broken till they are ready to unhair. In a good vault, where the heat is maintained between 44° and 56°, above which it should never be allowed to rise, and where there is a free circulation of *damp* air, the hides generally require from six to twelve days. If the temperature falls below 44°, the ventilator should be partially closed; but if it rises above 56°, cold damp air must be forced in, or a larger volume of spring water thrown into the pit.

MORFIT states, that the hides carried carefully through this process are, when received by the tanner from the beamsman's hands, free from all extraneous matter, and retain all their gelatin, albumen, and fibrin in an unimpaired state; and that it is not a fermentative change that produces the unhairing, because there is no ammonia generated. The effect is owing to the softening action of the absorbed vapor upon the epidermis, in conjunction with a swelling or distention of the roots of the hair, and tissue of the skin immediately underlaying them. Should these advantages be found, upon trial, attendant upon this simple and quite feasible method, it would undoubtedly be for the interest of tanners to adopt it, as not only does it require less labor, but the requirements in the shape of pits and water are still less than for the systems practised on this side the Atlantic, leaving the consideration of the great gain in the amount of leather out of the question; and which, of course, is its most powerful recommendation.

By Rhusma.—WARINGTON recommends a solution of carbonate of soda for unhairing the hides, but the effect is not so rapid as when the alkali is in the caustic state. The same chemist, in attempting to depilate hides by the use of *rhusma*, the long-known mixture of caustic lime and orpiment, or tersulphide of arsenic, discovered that the active agent was sulphide of calcium, formed by the decomposition of the arsenical compound in the presence of that base, and that *the arsenic* was without *effect* in the operation. He therefore tried the action of sulphide of calcium *per se*, and found that it acted so promptly, that only from twenty-four to thirty-six hours were required to soften the epidermis, and loosen the hair.

RAISING OR SWELLING.—After the removal of the hair and epidermis, and the bating, in case of hides intended as upper or pliable leather, it is necessary, to submit the *pelt*, as the depurated unhaired skin is commonly called, to a further operation, in order to distend its cellular organs, with the view of enabling it the more readily to combine with the tannin. In England, sulphuric acid, in the ratio of one part of acid to a thousand of water, is the agent usually employed for this purpose; but in some cases immersion for a limited period in the spent tan-liquor, wherein a certain quantity of gallic and other acids have been developed, is substituted, and even this treatment is abandoned by many, a weak tanning liquor being preferred. This is especially the case in France, where a prejudice exists against the use of sulphuric acid, founded on the opinion that it destroys many of the good qualities of the leather. When sulphuric acid is used, the swelling or raising is sufficiently executed by twenty-four hours' immersion in the bath. When kips and skins are under operation, the raising is done partly during the liming and partly by the *bating*, to which they are afterwards submitted. Allusion has already been made to the mode practised with excrements; but besides this, the same end—the removal of any residuary lime—is attained by the employment of barley meal, made into a sour liquor. For one hundred pounds of dry skin, fifty pounds of coarsely-ground barley meal, and five or six pounds of soured dough are taken, the whole being intimately distributed in the water. Lactic fermentation follows, and the acids generated form soluble salts with the lime in the skins, when the latter are immersed in the liquor, and the succeeding washing removes them. This bath is termed the *white* bate, to distinguish it from the *red* bate, or the aqueous washings of old used bark or tan. With this reddish brown liquid a number of vats are filled, the solution in the first being diluted so as to give them a gradation of strength. Before submitting the washed and unhaired skins to the series, they are steeped for a few days in summer, but a longer time—four or five days—in winter, in clean water, which is renewed every day, whilst the skins are left to drain for two or three hours. After this they are submitted to the first and weakest vat of the red bate, and after spending some time in it, they are transferred to the next, and so on, till they come to the last. During these operations the practice is to handle the skins morning and evening, leaving them to drain about three hours, whilst they are passing through the weak baths; but once a-day when they arrive at the stronger ones. Sometimes, in this way of working, the final bath are a solution of fresh tan, more or less concentrated, according to the views of the tanner. When the baths are rather concentrated, the period occupied in swelling by this method varies from a fortnight to three weeks.

The finishing of the *raising* is effected occasionally with strong tan-juice, which has been mixed by agitation with about four pounds of sulphuric acid. Eight or ten hides being submitted to this bath, they are taken out the first day twice, and permitted to soak or drain for two hours, the second day once, the same time being allowed for draining. In the morning of the third day they are transferred to another, composed of the densest tan-liquor, mixed with the same quantity of sulphuric acid as the foregoing. Whilst here, the hides are handled once a day, being allowed to drain at each handling one hour. About three days suffice to give them the necessary finish.

The red bate is regarded as being by far the best means in use, notwithstanding it is much slower in its effects than some of the others adopted in practice. This may arise from the fact, that the combination of the gelatinous tissue of the skin with the tannin is slowly going on from the immersion in the first vat of the series, at the same time that the lime is being removed, and, consequently, that the finished leather is more compact, and tougher, than if the swelling were made with acids in a shorter time.

The Tanning.—The many improvements in reference to the combination of tannin with the gelatinous tissue of the skin, that have been put in practice within the last fifty years, seem almost to exhaust the subject. Hydrostatical pressure, the laws of exosmosis and endosmosis, exhaustion, or the vacuum principle, combined with mechanical action, have been successively tried, and the result is, that the time required for the operation, which formerly extended over two years, and sometimes longer, is now diminished in some cases to as many weeks. Unfortunately, it appears that, as the period occupied in the tanning is diminished, so also is the quality of the leather deteriorated, for although by the modern accelerated processes, a large amount of tanning agent is rapidly taken up by the skin, its union with the gelatinous matter is far from being complete, and the pressure or exhaustion applied to bring about the rapid combination has the bad effect of leaving the leather porous, and without compactness or body. Hence, when a good article is required, such as shall combine density with closeness of grain and thorough homogeneous tanning, that which has been manufactured in a manner somewhat resembling the old system is still preferred.

This system consisted in spreading a layer of waste tan in the bottom of the pit, and over it another of fresh tan to the depth of an inch; upon the latter the hides was spread out evenly, and over it another stratum of tan. This alternate arrangement of tan and hides was continued till the pit was filled, when another layer of tan, six inches thick, was placed upon the whole, and well-trodden to compress the mass; the final covering was termed the *hat*. After a period of four months, when the bark was considered to be exhausted of its tannin, the contents of the pit were removed, the partially-tanned hides stretched, and again replaced with a supply of fresh tan in the same order as before, left for another interval of several months, then taken out, again stretched, and so on till they were deemed sufficiently tanned; the bloom being ultimately given with a concentrated extract of the bark. No moisture was allowed to enter the pit, except what was retained and absorbed hygroscopically by the bark; and as the tanning agent can come in contact with the skin only in a state of solution, it is evident that in the absence of sufficient liquid to bring it to this state, the method must have been slow and tedious.

Subsequently the plan was adopted of filling the pit with tepid water, the hides and bark being arranged as above stated, and new materials substituted for those exhausted every three or four months, till the tanning was nearly completed, the finish being given with a strong solution of tan liquor. Even by this course, which was a great improvement on the former, the hides took a period of eighteen months and longer to convert them into good leather. Another innovation followed; it consisted in filling the pit with tan-liquor or infusion of the bark, instead of water, the hides and bark being disposed as formerly. This mode is still much followed by Irish tanners, but is now deemed obsolete by most of the leather manufacturers of this and other countries. Leather can, however, be made by this method, unsurpassed by any other in quality.

It is rarely that ground tan is now used, the time of tanning being reduced, and leather of average excellence obtained by employing a solution or extract, termed *ooze*, instead. In the slow process of working, very little difference exists between the course followed by the various tanners; and where a difference is found, it is more in the manner of making the *ooze*, than in the succeeding manipulations. The adoption of solutions of tan has been gaining ground regularly from the time of Seguin, who first recommended it, and there is no doubt that it is much more effectual, as evidenced by the abridgement of the tanning period, than even the most finely powdered bark. There are several methods of preparing the ooze; cold water being employed by some; hot by others; while many extract the strength of the material by boiling; and, latterly, the spent or weak liquor from the pits has been resorted to for this purpose. When cold water is preferred, the better way is to have a gallery of vats, in which the ground tan is exposed to the solvent action of the water. That which receives the water direct from the reservoir contains the almost exhausted tan, and, consequently, as the liquid passes from one vat to another, it meets with a richer material, and takes up more and more tannin, until, as it passes off from the last filled with the fresh bark, it possesses a high degree of concentration.

The same plan may be followed when hot water is used, in which case branch steam-pipes are laid to each vat for the purpose of heating its contents. By this means the extract is obtained of any degree of concentration, according to the quantity of water employed, and the time of digestion allowed. Sumach, divi-divi, and valonia, may be exhausted in the same way; but kino, and the several varieties of catechu, should be macerated by repeated agitation in the water. Divi-divi extracts should be made as much as possible in close vessels out of contact with air; and the tanning, also, when this substance is used, ought to be performed with as little exposure as possible, with the view of preventing the coloration of the leather.

Latterly, hydrostatic pressure has been resorted to for abstracting the virtues from barks and similar substances. A well-bound vessel is taken, and a perforated false-bottom inserted a short distance above the real one, and from the space between the two, an outlet pipe draws off the contents. It must be fitted with a strong and water-tight cover, supplied with two trap-doors, through which the bark may be inserted and removed, but capable of being perfectly secured. When filled with the bark, water is introduced through a pipe, which may be twenty or thirty feet high. By keeping the latter always filled, considerable pressure is exerted upon the contents of the tub, and by this means the tannin is more readily dissolved. The liquor is drawn off from time to time through a pipe, according as it filters through the mass.

Whatever be the means adopted for making the ooze, the next operation is the immersion of the skins in it, in order to convert them into leather. This is done by filling a number of pits sunk in the floor of the tan-yard, and introducing into them the swelled or partly-raised skins, beginning with those pits which contain a weak infusion, and after proper intervals, passing the skins forward into those which contain stronger solutions. In the construction of these pits, the practice is to excavate the earth to the depth of nine or ten feet, and to cover the bottom with a bed of retentive clay. The pipes for conveying the ooze, waste, tan liquor, *et cetera*, are then laid, and the intermediate spaces filled in with well-compressed clay. Instead of boards, bricks are sometimes used, and the inner surface is well secured with hydraulic cement. A composition of asphalte, made of the usual components, only substituting clay for chalk, would answer the purpose admirably. Such pits as contain the weak infusion of the tanning agents are called *handlers*, and those employed for finishing the process, and, therefore, having a stronger liquor, are known as *layers* or *bloomers*. In the weak handlers, the hides are taken out twice a day, placed double one over another in a heap, and again introduced into the same or the next pit. After their removal to stronger pits, the handling, as the operation is called, is performed only once a day, and after they arrive at the layer-pits, they are taken out only once in the week, and finally once a month. The object of these handlings is to equalize and quicken the combination of the tannin with the skin; for during the time that the hides lie upon one another on the ledge over the pit, their weight forces the absorbed liquid out of their pores, so that they are more free to imbibe the juice on their re-introduction to it than before. Some are of opinion, however, that during the one or two hours they remain exposed, they contract some injury, and that the quality of the leather is much improved by transferring them at once into other pits; but, as will appear further on, a directly opposite view is often held. It is a common practice with many to introduce some powdered tan into the last pits or bloomers, between the hides, more especially when it is desired to produce a superior leather in point of quality and color. On the other hand, several manufacturers continue to use the powdered tan with the ooze throughout. To avoid the repeated handling of the hides, and the alleged injury from exposure, some tanners submit the hides to the tan-liquor in a vertical instead of a horizontal position. This method has the advantage of exposing every part of the skin to contact with the juice; but if care be not taken to alter the position at proper intervals, the lower part is liable to be better tanned than the upper, owing to the bottom of the pit containing the richer ooze. This, however, is very easily obviated by reversing the hides. Patents upon this principle were taken by Mr. KEASLEY in 1845, and by Mr. BARRETT in 1850.

The quantity of tan required varies with the weight and quality of the hides. Generally, heavy hides take about double their weight of good oak bark to tan them; but those which are lighter and of less body are perfectly tanned with a less quantity, from 1.6 to 1.8 of their weight. When sumac, valonia, divi-divi, or catechu is the tanning agent, a much less proportion suffices, since these materials, as already stated, are greatly richer in tannin than oak bark. With oak tan, the period required for tanning good sole leather averages ten months; about eight months when valonia is used; and six if *terra japonica* or catechu be employed.

The method of tanning introduced by M. OGEREAU of Paris, is similar to the old system still followed in many parts of Ireland and Scotland, namely, the stratification of the pit with alternate layers of tan and hide; only that, in the French method, the pit is furnished with a false or hurdle bottom, through which the liquor in the vat filters, and collects in the space below. Once a day or oftener, as the case may be, the filtered juice is raised by a pump to the top of the vat, from which it gradually descends through the materials, to be again successively raised to the surface. By this means the tan juice in the pit is kept in circulation, and brought into close contact with the hides. At the end of a month the contents become exhausted, and fresh materials are introduced, the circulation being kept up as before. It is said that by this method the time occupied in the tanning does not extend beyond four months, and that the leather is of first quality.

Nossiter, in 1844, patented a method by which the pressure of the overlaying hides in the pit, which prevents free contact with the tanning liquor, is counteracted, and the conversion of the hides into leather much accelerated. This method consists in constructing within the tan-pit a frame with ledges, which support other frames on which the skins are placed when introduced into the pit. Even when fixed as closely as possible together, as many skins cannot be introduced as in the old way; but taking into consideration the limited time in which the operations are finished, the patentee states that, in the end, a larger number can be tanned by this method within a given time than by the ordinary arrangement. After all the frames and hides are placed, the pit is filled with ooze, and after it has become exhausted, the spent liquor is pumped out and fresh supplied, and this is repeated till the leather is formed. Another improvement embraced in this patent consists in depriving the hides of the old tan-liquor previous to immersing them in the new, by submitting them in numbers at a time to the action of a screw-press, so constructed that the hides do not require to be folded, but are laid flat on the table or press-board.

The plan adopted by Berenger and Sterlingue for tanning hides in a reasonably short time, without the aid of machinery, is the following:—A row of pits is formed, each furnished with a hollow vertical wooden cylinder, connected with the next pit of the series by a pipe fixed at a depth of six inches from the surface, and communicating with the space between the perforated and true bottom, by means of a punctured pipe. By this arrangement, the liquid in each pit may be made to pass over to the next in the series, and so to the end, without the least disturbance of the contents. Thus, if water from the supply pipe be conveyed into the first vertical cylinder in the series, the liquid flows down through the false bottom into the intervening space, causing the fluid already there to ascend through the body of the vat, and to flow over by the connecting pipe into the cylinder of No. 2 pit, where it displaces an equal volume of liquor in like manner. In working on this principle, a series of eight pits is preferred; No. 1 is filled with tan and hides in the old manner, and as much water as it will retain added. After twenty-one days, No. 2 is filled in the same way; but instead of employing water, as much strong ooze as is required to wet the materials is poured into the first pit, and this drives before it the weak liquor, which ascending by the pipe from the false bottom into the cylinder, flows over by the connecting pipe into, and moistens the contents of, No. 2, with the weak tan liquor of the first pit. After the lapse of another period, a third is charged with tan and skins, and after this a quantity of strong ooze, equal in bulk to what is necessary to moisten the contents of the new materials like the others, is poured into No. 1, when the liquor previously contained in it will flow over from the cylinder to No. 2, the liquid contents of which are in like manner transferred to No. 3. In this way the work progresses till the eight pits are filled. The connecting pipe of No. 1 is then closed, and the ooze in it pumped out, and the remaining materials removed, when the leather will be found thoroughly tanned. A fresh supply of hides and tan are then put into this pit, which now becomes the last or eighth of the series, that which before was No. 2 becoming No. 1, and receiving the strong ooze. By this means the hides are tanned without once removing them from the pits till they are finished, and likewise with a great saving of labor. If the strong infusion be added at intervals of fifteen days, the time required does not extend beyond four months, but it may be prolonged at will, by allowing a period of twenty or thirty days to elapse between the addition of fresh ooze, or the filling of a new pit. The ooze used in the foregoing operation is prepared in a series of vats similarly constructed, or they may be placed one above another, so that the liquid in the higher may flow into the next beneath, as in the lixiviation of soda or of kelp—see Iodine—only that each is furnished with a coil of steam-piping, for the purpose of heating and concentrating the liquors, with a view to the removal of gallic acid and other substances. The liquor emptied from the tan vat is mixed with the ground bark or other material in the first of these, and after a while, the solution is drawn off to the lower one, where it becomes further enriched. In this way the liquid may be brought to any degree of density necessary for the operation, and much of the extractive and gallic acid may be removed.

Another patent process by Cagswell, recommends the process of filtration, as a means of causing the tannin of the ooze to unite with the matter of the hide in a shorter time than is ordinarily required. The prepared hides are to be laid in sawdust, in such a way as to form a kind of basin, and into this the rich ooze is poured. Gradually it finds a passage through the cells of the skin, and passing out at the other side, runs through the sawdust into a tank beneath or adjacent to the floor, but whilst going through the hide, the tannin is retained. By keeping the hollow of the hide filled with fresh ooze, the gelatino-fibrous tissue in a very short time becomes saturated with tan. There are some drawbacks, however, to this method; for instance, the porosity of the hide is very unequal, and as the filtration is greater where most porous, these parts are liable to be overtanned, when the others may not be sufficiently so. Again, the edges are never finished in this operation, and consequently, the hides, after the body has been made into leather, must be subjected to ooze in the pit. The great space, too, necessary to carry on an extensive trade by this means, is not among the least objections to it.

Besides the preceding methods in which the tanning agent is left free to react upon the skins, several others have been patented in which mechanical force, in concert with other means, has been employed to effect the tanning in a shorter time. The simplest of these are such as merely cause the agitation of the hides and tan-liquor in the vat, so as to effect a more thorough and rapid contact of the combining substances. Of several on this principle, that of Mr. Squire of Warrington, patented in 1845, will be sufficient to illustrate the method pursued. A cylindrical drum or barrel is divided internally into four compartments by bars, space being left for the liquid of one part to flow into the next as required. The hides are introduced into these divisions by doors which are well secured, and the tan-liquor, which may be that of divi-divi, catechu, or any other, in quantity sufficient to fill the cylinder to more than three-fourths. All the openings are then perfectly secured, and motion is given to the apparatus by means of a winch fixed upon its axis, or a strap passing over a drum, and connected with the engine shaft. The rotation is slow, but sufficient to keep the hides and fluid contents in motion. In the course of a very short time the hides are well tanned by this method, and the air being excluded during almost the whole period, the leather retains a good appearance, even when divi-divi and catechu are the agents employed.

Some erect a roller over the mouth of the pit, and string the hides together by stitching in the form of an endless web or belt, which is wound in several coils loosely round the roller, and then placed so as to be partly submerged in the ooze of the pit. By turning the cylinder, the immersed portion becomes saturated with the liquid; and as it rises again on the roller, the weight of the suspended hides exercises a force by which considerable quantities of the liquor are squeezed out, and the hides descend at the other side in a condition to absorb fresh liquor. This alternate absorption and expression of the liquor is very conducive to rapid tanning; but the time is still further abridged by a process patented in 1837 by Cox and Herapath, which consists in passing the hides between two rollers fixed longitudinally over the pit. In order to avoid injury to the hides from contact with the metallic surface of the rollers, and to allow the solution to pass away more readily, the lower cylinder is covered with horse-hair cloth, and the upper one with folds of flannel. Both rollers revolve, and the upper one may be weighted to any degree, so that the hides passing between them lose all absorbed water and re-enter the same pit, or another containing a stronger ooze, in a condition to imbibe the solution very readily. It is stated that sole leather may be thoroughly tanned by this method in one to two months, and kips for upper leather in three or four weeks. It should be remarked, however, that although with care an average quality of leather may be prepared in this manner, yet, if too much pressure be exerted, the process of tanning will be rather retarded than otherwise, because the elasticity of the tissue will be destroyed.

Tanning by Hydrostatic Pressure.—Spilsbury, in 1831, was the first to introduce the method of permeating the hides by hydrostatic pressure. His mode consists in securing any holes or damaged parts in the hide, and then to stretch it on a suitable frame, having iron hooks for fastening the edges of the skin all round. Upon the frame so furnished another is laid, and screwed tightly, so as to allow no room even for water to percolate between the two frames. Another hide is then fixed upon the second frame, and its edges secured in the same manner by a third frame, the whole three being bolted firmly together by means of clamps. In this way a kind of water-tight compartment is formed between the two hides. The frames are then placed upright, and the interval between the hides is filled with ooze. As the skins form the side walls, it is evident that their whole surface will be exposed simultaneously to the liquor, and as the latter by the force of its own weight penetrates them, the tannin enters into combination, and they are gradually converted into leather. An arrangement of pipes and stopcocks permits the confined air to escape in the first instance, and afterwards the spent liquor, after it has percolated through the hides. Of course the rapidity of the tanning by this, as by other processes, depends more or less upon the thickness of the hides, the strength of the ooze, and the amount of pressure exerted.

Drake, instead of using frames, directs that the hides should first be submitted to an incipient tanning, and then sewed together in pairs, so as to form a kind of sack. A small aperture is left at the shoulder or neck part for the introduction of a funnel for filling the sewed hide with the tanning juice; and to prevent the distension to which the hides would be liable on being filled, he places each pair in an upright frame of suitable size. The bag being filled with the ooze, the liquid percolates through the pores of the skins, being deprived of the tannin in its passage, and trickles down into a receptacle beneath the frame, whence, if rich in tannin, it is pumped back into the bag in order to be again exuded. Towards the close of the operation, when the skins become firm and hard, so that the confined fluid exudes very slowly, the atmosphere of the room is heated to about 150°, with the view of promoting the permeation of the ooze, and the process is continued till the hides give indications of being thoroughly saturated with tannic acid, which is known by their beginning to darken in places, and by the passing through of the ooze without losing strength. The contents of the bag are then withdrawn, the stitchings cut open, and the leather subjected to the finishing processes, which will be presently described.

By the improved methods of Chaplin and Cox, the hides are sewed up into bags, leaving a small aperture for the introduction of a branch pipe from the main, connecting them with a tank which holds *hot ooze.* On turning a tap, the ooze flows into the bags by means of the branch pipes; and provided the connection and sewing be secure, the pressure exerted may be varied at pleasure, according to the height and quantity of liquor in the vat. As the hides are necessarily extended more or less under the force so exerted, frames answering to the size of the bags are used to keep them from bursting or being too much expanded. The plan of encasing the sewed hides in canvas or flannel, has been patented as an improvement on the practice of placing them in frames or boxes of wood.

Peachy, Poole, and others employ force pumps and other similar means to cause the tan-liquor to penetrate the hide, but the principle of hydrostatic pressure is still retained.

All these methods by infiltration are subject to the disadvantage arising from the unequal permeability of the hides at different parts, and from the weakening of their structure consequent on the prolonged distension.

By Exhaustion of Air.—Knowlis and Duesbury, to avoid the evils which hydrostatic pressure occasioned, had recourse to infiltration produced by the exhaustion or rarefaction of the air in the vat, in order to tan the hides more regularly. For this purpose the hides are suspended within an air-tight vessel from cross beams furnished with hooks. To economise room, they are arranged as closely as possible without touching, and weighted beneath to keep them extended. The top of the vessel is movable, and the pipes for exhausting the air by the pump, or for forcing air into the apparatus, are fixed at the sides near the top. When ooze has been introduced till the hides are covered, and the lid is firmly screwed down, the air is exhausted, and the contents left to their natural reactions for twenty-four hours or more. The air is then admitted, and the ooze drawn off. During three hours the hides are now left in the vessel in contact with the air, till in fact they become saturated with it, and when this period has elapsed, the tan liquid is again introduced, and the exhaustion renewed. In this way, the alternate filling of the vat with liquor, exhaustion, and exposure to air, are continued till the leather is fully formed, taking the precaution to employ stronger ooze as the operation proceeds.

By endosmosis.—The process patented by TURNBULL in 1845 embraces a combination of the exosmotic and endosmotic principles. The hides, sewed into bags, are filled with the ground tanning material and water, or a weak ooze, and the bags are then immersed in a vat filled with a strong extract of catechu, freed as much as possible from catechuic acid by solution in cold water and filtration. The inequality of density between the weaker liquid within the bags, and the stronger solution contained in the vats, causes a motion by which the exterior penetrates, and the interior solution exudes, both parting with tannin to the gelatino-fibrous tissue, and causing its saturation in a very short time without the intervention of any mechanical force. To expedite the operation, the liquid in the vats is rendered denser by dissolving in it salts or sugar in the proportion of fourteen pounds to one hundred gallons. During the tanning, it is necessary to keep the bags filled by occasional additions of water or weak ooze, and likewise to maintain the density of the liquor in which they are immersed, as this causes the endosmosis or infiltration, and consequently the exosmosis or exudation, to be more rapid.

By acupuncture.—SCHNYDER, some few years ago, obtained a patent for a quick process of tanning, effected by exposing a more extended surface of hide to the tan-liquor than is ordinarily done. His method is to puncture the hides with steel points either by hand or machinery, with an instrument having from one to three hundred points to the square inch, and afterwards to expose the skins so indented to the action of the tan-juice, with or without pressure, as may be most convenient. Either the flesh or hair side may be operated upon with the steel points; and, notwithstanding that such perforations permit the liquor to enter into the interior portions of the skin, still, as the tanning approaches completion, they close up, and the leather is as capable of resisting moisture as that made from hides which have not been subjected to the same operation.

According to MORFIT, this method is more worthy of attention than most others, owing to the combination being so readily effected between the skin and tan that the ooze has not time to acidify before it becomes exhausted, and so the relaxation and expansion of the fibres, the enlargement of the grain, and consequent brittleness of the leather which acids produce, are obviated. Also, because by this method the formation of leather takes place in the heart of the hide as readily as at the surface, the overtanning of the latter, by which it becomes rigid and brittle under the old system of prolonged exposure in the tan vat, is done away with.

Mineral Tanning.—It has been shown in the introductory portion of this article that gelatin, fibrin, and albumen, are capable of combining with and precipitating metallic oxides and basic salts from their solutions. On this reaction have been founded certain processes for converting skins into what may be called a *mineral leather*, by impregnating them with suitable metallic bases. This is easily effected by merely placing the raised and depilated hide in contact with solutions of such bases, when the affinity of the gelatino-fibrous tissue for the mineral compounds results in their combination. Alum has long been known as a compound capable of rendering light skins imputrescible—in fact, of converting them into leather; but this agent has not been used for making ox or such hides into sole or upper leather till lately. The first to draw attention to the manufacture of leather suitable for all ordinary purposes, without the aid of tannin—considered as a branch of trade—were D'ARCET and ASHTON; but their attempts, although they suggested the idea, left very much to their successors to accomplish.

BORDIER, in 1842, obtained a patent for an improvement in this department, which deserves more attention than the methods of his predecessors. On this system the hides are to be washed, depilated, and raised by any effectual method, and then exposed to the mineral constituent, which consists of a subsulphate of sesquioxide of iron, prepared by digesting twenty-two pounds of protosulphate of iron—copperas—in a mixture of two parts and a quarter of nitric acid, specific gravity 1·33, and three pounds one ounce of sulphuric acid, of 1·848 density. A stone-ware jar may be employed for this purpose, the contents to be heated with steam, and stirred repeatedly. As soon as the red fumes of peroxide of nitrogen—NO_4—cease to be evolved, the vessel is to be removed from the heat, and the mixture kept agitated, till, as it cools, it forms a kind of paste. After settling for twenty-four hours, it is to be diluted with water, and some further portion of sesquioxide of iron added. It is again left for several days, with occasional stirring, for the purpose of allowing the sulphuric acid to take up the sesquioxide of iron and retain it in solution. The cleaned skins are then immersed in the bath, and stirred about or handled occasionally, as when working in the tan-pit, till they are made into leather. With light skins this happens in three days or thereabouts, and in six to eight days with thick skins intended for sole leather. During this immersion a combination of a basic salt—a subsulphate of the sesquioxide of iron—takes place, and an acid salt with uncombined sesquioxide remains in the bath. There is little doubt that the acid liberated in consequence of the union of the base with the skin must have an injurious effect upon the leather, as is the case when tan is used; and if this be so, a method of working in which the uncombined acid might be neutralized as soon as disengaged from the iron base, would be preferable.

CAVALIN'S mode is to impregnate the cleansed, depilated, and partially-drained hides, with a solution made of ten pounds of bichromate of potassa and twenty of alum, in one hundred and eighty pounds of water. For this end they are immersed during four days, being handled once in the twenty-four hours, and rubbed, if necessary. Much of the success of the finishing process depends on the thorough manner in which this first saturation is performed, and therefore the strength or density of the bath is kept up by the addition of more of the above salts, in proportion as the hides absorb what has been already dissolved. For the second step in the process, the vat is filled with a solution of copperas—protosulphate of iron—using one pound of this salt for every gallon of water. The hides saturated with the alumino-chromic solution are immersed in this bath in such a way as not to touch one another, nor the walls of the vat. At an interval of twelve hours they are drawn out, allowed to drain for a short time, and again plunged into the bath; the alternate draining and immersion being thus continued till the leather is formed. It is necessary to maintain the strength of the bath, as the iron enters into combination, by adding more of the salt. In this operation the iron base is peroxidised in the hide by means of the chromic acid, which is itself reduced to the state of sesquioxide, and remains, with the iron and a portion of the alumina base, firmly united with the tissue. The time extends over from five to six days for upper leather, eight or ten for Swedish sole leather, and thirteen to nineteen for thick *butts*. After the finishing of the operation, the hides are drained, and then thoroughly soaked in water to remove everything that has not entered into combination. Upper leather prepared by this method is said to be soft and pliant; and the thick sole leather is alleged to have a body and imperviousness that render it equal for wear to the best tanned leather. The same inventor recommends another method of making leather of skins, by first submitting them to a dyeing process, employing a strong dye beck, in which four ounces of alum are added to the gallon of liquor. Frequent immersion in this solution reduced to the proper strength—as determined by a preliminary test with a bit of prepared skin—is necessary, till the materials assume a light-green yellow color on the grain, and yellow-green on the flesh side; after this they are drained and finished in a bath made by dissolving ten pounds of bichromate of potassa in eighteen gallons of water.

FINISHING PROCESSES.—Such are the principal methods followed in the tanning of hides, but after this operation has been performed, the hides are not in a fit condition for the market; they have still to be submitted to several additional processes. When thoroughly tanned, the hides are taken out of the layers or bloomers, and washed slightly, or brushed with water to remove all extraneous matters, without, however, detaching the bloom which is so much prized, and is regarded as a kind of guarantee for the quality of the leather. They are then hung up to dry in a spacious and well-ventilated apartment, from which the sun's rays are excluded. Much care is necessary in the drying: if conducted too rapidly, the hide is liable to crack on the grain side, owing to the rapid and unequal contraction of the inner and outer parts; on the other hand, it must not be so slow as to allow the leather to get mouldy. In winter, a medium temperature is maintained in the drying-room, or loft, by means of steam-pipes, judiciously placed so as to give out their caloric to the air of the place. When partially dried, the leather intended for soles and other similar uses where great impermeability is required, is submitted to a process for condensing it, and destroying in a great measure the porosity which it retains after the tanning has been executed. Formerly, this was done by hammering the leather on a smooth table with heavy mallets or hammers, almost in the same way as the shoemaker hammers his leather upon the lapstone; but subsequently machinery was substituted. In many concerns, the compression is effected by means of rollers of brass surmounted by a carriage, loaded with ten to thirteen hundredweight.

STERLINGUE was the first to introduce a hammer moved by machinery for condensing the leather, but in his invention numerous requisites were found wanting, so that it was often necessary to finish the leather by hand with the hammer or mallet. In 1840, DEBERGUE patented another apparatus, in which a roller attached to a weighted lever, with other regulating mechanism, was the compressing agent. The hide or side of leather being placed upon a strong table faced with brass, and having either a plane or concave surface, was submitted to the action of the roller. COX and WILTSE have lately introduced machines which are analogous in their action to the preceding, but are simpler in their construction. Another machine was introduced by M.M. IRAN and SCELLOS in 1852, of which report speaks favorably; but as the object of all these machines, of which there is a great variety, is simply uniform compression, either by beating or rolling; and as the details of their construction would too much extend this article, the Editor forbears to enlarge upon a subject purely mechanical.

After the rolling or hammering, as the case may be, the sides of leather are hung up again to dry, and left with occasional changes of position, till all the moisture is removed as far as possible. After this, the sides are in some instances stored by laying them one above another, and weighted; their position being changed from time to time before they are sent to the market. This storage is supposed by many to improve the quality and color of the leather, but others regard it as unnecessary trouble.

CURRYING.—Such are the processes through which heavy or sole leather passes. With upper leather, or that prepared from lighter skins, a different course is pursued—the rolling or hammering being dispensed with, and another set of operations termed *currying* being practised. In some cases, the finishing of the leather to suit the shoemaker, coach, and harness manufacturer, becomes a distinct and independent branch of business from that of the tanner; but in many establishments, the two are carried on together, so that the finished leather issues from the tannery.

To curry leather, so as to confer qualities which adapt it for the boot and shoe maker, the carriage and harness maker, and other particular applications, requires its subjection to various processes, which, independently of the tanning, according as they are well or imperfectly accomplished, affect in a great measure the suitability and lasting qualities of the leather. From the difference of treatment which becomes necessary to confer these qualities, result the numerous designations by which the finished material is known. Thus, a distinction is made between smooth or sleek leather, tallowed, oiled, and waxed leather, with several other varieties. In the variety and quality of their curried leather, the manufacturers of Great Britain are far behind their French brethren. The heavy upper and harness leather produced by the British currier cannot be excelled; but when a light article is required for summer wear, and which should retain its suppleness, the inferiority of the British leather, compared to the French, becomes apparent to the wearer after a very short time.

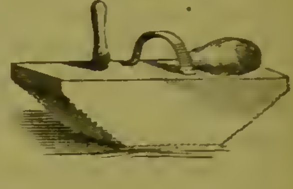
The role of operations required for this finishing may be enumerated—the dipping or soaking, the beating, stretching, oiling, tallowing, waxing, dyeing, and polishing.

Soaking and Beating.—As the tanned hides or skins come from the tanner they are dry and hard, but before they can be submitted to any of the finishing operations of the currier, they must be rendered soft and pliable. This is done by soaking them in water, or sprinkling them with that liquid, and allowing them to rest till they become sufficiently moist. When this happens, the side is placed upon a rectangular hurdle of basket-work, and trodden with the feet—the operator wearing heavy wide shoes for the purpose—or else beaten with an instrument called a *mace*. The working is continued carefully so as not to tear or injure the leather, till it becomes sufficiently soft and pliant, and when this is effected, it is placed upon the horse, and worked with the *cleaner*. There are various kinds of this tool, but, in all cases, the sharp edge of the instrument is so formed as to prevent it entering too far into the leather. By its use, the inequalities and overtanned parts on the flesh side are shaved off, and an uniformity of thickness and regularity of surface produced.

Stretching.—By the preceding treatment, the grain of the leather is brought out, but the desired equality is not attained till after it has undergone the *stretching* and *pommeling*. The former is executed by means of tools of steel, copper, or brass, or of hard stone or glass, the latter materials being resorted to when a better and smoother surface is desired. After the shaving on the horse or beam with the knife, the skin is further soaked in cold water and scoured, then placed with the flesh side under upon a smooth stone or mahogany; and the workman, grasping the wooden handle of the stretcher in both hands, holds the tool almost perpendicular to the side of leather, and forcibly scrapes the surface, especially where there appears to be inequalities. By continuing this action, usually from the tail to the head part, over the entire surface, and using water freely in sprinkling, the whole is brought to an equal thickness at the same time that it is stretched, and the *bloom* of the leather more developed; density and smoothness are also acquired.

Pommeling.—The partially prepared hide is now submitted to the last operation called *pommeling* or boarding. The pommel is of hard wood, having a smooth and fluted or channeled side, the former being next the hand, and the latter for acting on the leather. Fig. 351 shows this instrument with the strop intended to confine the hand of the workman, so as to give him greater power for applying it. According to the fineness of grain required, so do the grooves in the pommeler or crippling board become finer and sharper. Usually the grooved side of this instrument forms an arc of a circle, and the surface next the hand being straight, forms as it were the chord of that arc. This construction allows of considerable body in the middle part, whilst at the extremities it is thin. In using it the workman doubles the hide with the grain side in contact, and strongly rubs it on the flesh side, applying the force outwards, and then reversing it. This mode of working is ordinarily termed the *graining*, to distinguish it from the *bruising*, which takes place when the operation is performed on the grain side of the leather. In many instances the hides are again damped, and worked under the *slicker* or *stretcher*, and then dried and placed one upon another, and weighted for some time in order to complete the process; or they may be whitened by rubbing the flesh side with a sharp knife on the horse, after the action of the *grainer*, in which state, provided the leather be treated with oil or tallow before the last workings, it is known as *finished russet*. Leather prepared in this fashion is called *stretched* leather, but it may be made into *sleek* or *grain* leather by a few further operations, and a very slight modification of those described.

Fig. 351.



Grained Leather.—To render the hides—which are in most cases cut in two and pared—pliant and even in body, they are drawn over a flame from straw or such material, the flesh side being that so exposed. Fatty matters, which vary with the choice of the currier, though tallow or mutton suet is preferred, dissolved if required by heat, are then laid on the flesh side in a coating, by means of a brush or mop, to the extent of three to four and a half pounds for cow hides, and one for thick calf skins. After this *dubbing*, as it is called, the hides or skins are doubled up, the hair side being inwards, and remain so for some hours, or in some instances one or two days; they are then refolded, and put into a tub containing water, where they soak for eight or ten hours, being worked during this time more or less, so as to detach the fatty matter on the surface of the leather. When the whole of the pieces assume a uniformly white appearance, they are taken from the soak, and beaten with a *mace*, afterwards worked by the pommel till the grain is brought out, then cleaned with the sharp knife on the horse or beam, and finally, any creases removed by working and polishing them with the brass and glass slicker. This being done, the leather is slightly sprinkled with water, and, if necessary, cleaned and then hung up to dry. When it is required to color the product, the latter operation is not carried too far, so as not to necessitate its moistening again. The operator now rubs on the hair side, by means of a brush, a solution consisting of a sesquiacetate of iron, prepared by digesting scrap-iron in sour lies or beer, or of logwood, nut-galls, gum, and copperas.

Several coatings with such a composition are applied, the leather being partially dried after each, folded up, and worked under the stretching and polishing iron in order to give the finish. Before being sent out, however, it is rubbed over once or oftener on the grain side with a piece of woollen stuff dipped in sour beer or barberry juice, worked by the pommel and slicker, and finally, exsiccated. This kind of leather is much used by the saddler, trunk, harness, and coach makers. Of course, very many modifications in the order of application and execution of the foregoing treatment of the hides are practised by different parties, but the preceding general view of the operations will indicate the nature of the business.

Oil Leather.—Calf and cow leathers are curried in oil very extensively. The preliminary dipping, treading or working, *et cetera*, are applied, in order to give the substance more suppleness. Fish oil is recommended, but the French prefer the material usually employed for scouring skins that are intended for chamois leather, and which consists of fish oil and potassa. It is thicker than the ordinary oil, and becomes more rapidly absorbed; besides it gives greater pliancy and softness, and less is required than of the fish oil alone. Neat's-foot oil is likewise used, and it is said to add materially to the good qualities of the leather, but a proportion of fish oil must be mixed with it. When applying the dressing or oily matter, the skins should be slightly moist, so that, as they dry, the oleaginous portion may be gradually and thoroughly absorbed. Should they be too dry, the oil would be soaked too quickly, yet not properly combined so as to render it sufficiently resisting to water or moisture; on the other hand, excess of moisture must be guarded against, as in this instance too much oil would be expended, and the time would be prolonged in proportion. A coating of oil is uniformly spread over the grain and flesh sides, after which the hides are hung up to dry, the direct rays of the sun or too violent a draught being guarded against. In summer time the drying is effected in twelve hours, though in winter it sometimes requires three or four days. When dry, they are again fulled, and a further coating of fish oil mixed with the fatty scourings already mentioned, only in smaller quantity than in the previous case, laid on, and the process is repeated after the drying of the leather as before. Finally, the grain side is cleaned by rubbing it well with a brush and a weak potassa lie. The coloring of the grain or flesh side, as the case may be, follows these operations, and is effected by employing the dye already alluded to. After receiving one coat, the leather is pommeled crosswise; another layer of blacking applied; dried and pommeled, or stretched, according as it is deemed necessary; rubbed over with a cork pommel to give a smooth surface, and finished by giving a light coating of oil on the hair side.

Varnished Leather.—During the last few years a considerable quantity of a light glazed or varnished leather, intended for the manufacture of patent boots and shoes, has been introduced into the market. The French are celebrated for the beauty and superior quality of their manufactured product. This kind of leather is simply tanned kips, calf-skins, or split ox-hides of superior quality, well curried, and then passed through two other operations—one intended to render the leather impermeable to the varnish, and the other the laying on of the varnish. In currying leather intended for this manufacture, it is necessary that the fatty or oleaginous matter be laid on as thinly and evenly as possible, in order to insure the uniformity of the article after being prepared.

Such curried skins are taken and rubbed over, either on the flesh or grain side, with a coating of boiled linseed oil mixed intimately with ochre, ground chalk, or some such substance, and dried; the coatings are renewed after each desiccation till it has received three, after which the surface is well rubbed over with a pumice-stone tool till it appears even, and the fatty and other matter is compressed into the pores of the leather. When this is done, other layers of a thinner material than the above, but of the same nature, are applied, and after drying, rubbed into the skin as before; by which means the adjacent part of the skin becomes thoroughly saturated with the fat, and an even surface is given to it. After this part of the work is executed, the prepared surface is coated over two or three times with a composition made with boiled linseed oil, but without mineral matters; subsequently adding lamp-black and as much turpentine as will make it flow freely. This is laid on evenly with a fine brush, and allowed to dry after each coat, till a sufficiently black and shining surface is given to it; for which purpose it is rubbed over with a piece of woollen stuff and the finest kind of pumice-powder or tripoli.

The leather is now ready to undergo the final operation or varnishing, which consists in laying on coats of a composition made of boiled linseed and copal varnish, with which any coloring matter intended to show on the leather is incorporated. Generally this is composed of twenty pounds of boiled linseed oil, such as is employed in the first operation, twenty of turpentine, ten of thick copal varnish, and one pound of asphalte, Prussian blue, or ivory black in the finest possible state of division. In making it, the oil and tinctorial matter in finest powder are incorporated, then the varnish is added, and finally the turpentine, the whole being so well stirred as to insure a homogeneous mixture. It is then set aside in a warm place for two or three weeks, after which it is ready for use. It is necessary that the utmost cleanliness in regard to the manufacture be observed, and that no dust or other matters bo allowed to float in the atmosphere, either of the apartment wherein the coatings are given, or in that of the drying chamber, as this would injure the smoothness and brilliancy of the article.

The number of varnish coatings applied varies, but five is the ordinary limit, the drying being effected after each in the chamber intended for the purpose, the temperature of which is kept at 160° and under. In this way a brilliant surface is given, and the leather has the property of resisting strains and of bending without the least crack or any injury to the even and perfect surface of the varnish.

It has been stated that the black varnish generally used for boot and shoe leather, is colored with lampblack and Prussian blue, but the tint may be varied; thus for blue leather, Prussian blue or ultramarine mixed with a little Krem's white, and incorporated with the varnishes, answers well; lakes are used to give a red color; white lead for white; ochres for yellow, and so on, the shade being varied at will. An inferior quality of polished leather is made for belts and coach harness, by impregnating the skins with the linseed oil varnish, mixed at once with the lampblack and Prussian blue, copal varnish and turpentine. The linseed oil varnish is made by boiling, say, five gallons of this material with four pounds and a quarter of white lead and an equal weight of litharge, till the compound acquires the thickness of a dense sirup. For particular uses this is mixed with ochre, powdered chalk, or ground bones, as in the first operation for making a superior dress-boot leather.

Nossiter of Birmingham obtained a patent for making sheep and goat skin leather into this article. He splits it by machinery and, on the new surface produced by the section, forms a grain by polishing with a slicker, and then lays on the varnish. It is said that by this means a better surface is obtained than when the outside, either on the hair or flesh side, is operated upon.

Split Leather.—With reference to the preceding patent it may be here stated, that a considerable number of hides are now split by machinery, generally after receiving a slight tanning, and the divided parts afterwards fully tanned and curried, so as to adapt them for the manufacture of light boots, shoes, and other applications. It is almost unnecessary to remark, that leather which has been subjected to this operation, is much weaker than that which is manufactured in the entire state. A large proportion of cheap and inferior articles are formed of split leathers. Ox hides, kips, and skins, so split and tanned, are chiefly used by shoe and boot makers for the inner soles, by trunk and portmanteau makers, and in carriage facturing; whilst the sheep and goat skins, similarly treated, are converted into the finer kinds of glove leather.

Fancy Leathers.—Besides the various kinds of leather already described, there are many others, included under the name of *fancy* leathers, which are extensively used, and are therefore manufactured on a large scale. Such are the well-known Russian leather, *morocco*, Hungarian, and chamois leathers, with a few others of lesser importance, but which, nevertheless, merit a short description.

Russian Leather.—This article, known as *jucten*, has long been valued for its qualities of resisting moisture and the ravages of insects, as well as by the peculiar odor it possesses—qualities which render it of great importance to book-binders and others. Russia was long the only country that produced it, but it has lately been manufactured in Paris. Its odor and particular qualities are attributed to the essential oil of birch bark, with which it it is impregnated after the tanning with this material. In Russia it is manufactured from all kinds of skins, but in Paris, and wherever else the product is imitated, only sheep and goat skins are operated upon.

The method of preparing this article, is not very generally known out of the seats of the manufacture, but the following details from the memoir of Count de Kartsoff on the subject will give an insight into the process:—The dried skins are softened by soaking in water for five or six days in summer, and ten or twelve in winter; well cleaned and deprived of their hair by the use of milk-of-lime, prepared by disseminating one hundred and eighty-five pounds in a vat or tub eight feet in diameter, and seven feet three inches deep, nearly filled with water. During the steeping the skins are frequently examined, and as soon as the hair and epidermis are found to be detached, they are worked upon the beam with a dull knife, and afterwards with a sharper instrument, on the flesh side, to separate extraneous matter. When ox and cow hides are operated upon, the depilation is effected by piling them one upon another, sprinkling some common salt upon them to resist the injurious effects of over-fermentation, and after the proper time has been allowed, working on the beam as before. Bran-water baths are occasionally resorted to for the same purpose, but only when the more delicate skins are treated.

The usual steeping and beating, *et cetera*, are given after the depilation, with the view of removing the lime; and after this is done, the cleaned pelts are introduced into a vat like that described, containing a fermented menstruum of eleven hundred pounds of rye, and four hundred and fifty of oatmeal, six pounds of salt, and a sufficient quantity of leaven. They remain here for forty-eight hours or longer, according to circumstances, in which time they become *raised*. The tanning process is then commenced by steeping them for some time in a weak infusion of oak or willow bark by preference. After this the skins are placed in a tan-pit, interstratified with layers of coarse willow bark till it is full, and then charged with the liquor of the last steep, the whole being pressed by planks and stones. Fifteen to twenty-eight days are allowed to transpire before they are disturbed; at the end of this period the pit is emptied, fresh bark and solution substituted for the exhausted material, and the whole left as before. Three to six such changes and terms are required, according to thickness and weight of the skins, to finish the tanning; very thin skins get but two changes. Whilst tanning, the leather acquires rigidity, which is removed by immersion for a day or longer in a thin paste made of one hundred and thirty pounds of oatmeal, and nine of salt, macerated with warm water. This quantity should serve for one hundred and fifty skins of ordinary size. When taken out of this steep, the leather is well cleaned, and allowed to drain. At this juncture the currying commences, which confers the particular virtues already mentioned. The leather still moist, but not over-saturated, is placed with the grain side downwards on a table, and erated with a mixture of oil obtained from *sea calves*, and that distilled from birch bark; the proportions are varied according to circumstances, but for the most part, one of birch oil to two parts of the other is the standard composition. This, in quantity of about nine ounces to each medium-sized skin, is laid on with the hand so carefully as to insure an even and entire coat. This done, the skins are stretched upon cords in an open shed, and left so till dried.

The Baskirs and Kirguises prepare their skins by smoking them, in lieu of tanning. The hair is detached by scraping them, while in the green state, with a broken sickle attached to a handle. When this is done, the skins are attached to cords placed parallel to one another in a pit, the depth and breadth of which depends upon the number of skins to be treated at once, and which is connected with another, at the distance of five feet, by a tunnel at the bottom. The pit containing the skins is well covered, and a fire of dry and decayed wood lighted in the other, which is likewise protected. As no immediate means of escape exists, the smoke passes over into the pit charged with the skins, by the tunnel or gutter at the bottom, and in the course of two or three weeks that they are exposed to its action, converts them into a leather which is said to possess a degree of impermeability superior to that of any tanned leather.

The method pursued in France for making Russian leather is as follows:—

The skins are deprived of hair by steeping in a lime vat, or in one containing a mixture of lime and potassa lie, but too weak to act upon the fibre, and scraping on the beam; they are then rinsed and fulled for a longer or shorter period, according to their body, and subsequently allowed to ferment in a steep, being first well washed in hot water. Eight days are allowed for this operation, at the end of which time they are taken out, again fulled and washed, and, if necessary, submitted a second time to the vat, in order to open all the pores. When this is properly done, they are taken out, well washed, placed on the beam, and worked with the flesher on both sides. After this a paste is made, sufficient for two hundred skins, of thirty-eight pounds of rye-flour. This is allowed to ferment, then diluted with a sufficient volume of water, and the skins are immersed in it during forty-eight hours; and at the end of this time they are transferred to smaller vats, and allowed to remain in them for fifteen days, when they are taken out and well washed in running water.

They are now fit for the tanning, which is done by putting them into vats filled with extract of willow bark—*salix cinerea* and *salix caprea*—of such a degree of heat as will not injure the animal fibre. Whilst in this solution—usually a week—the skins are handled twice daily, and pressed for half an hour each time; after this the decoction is renewed, and the same course followed as when in the first bath, the time in the second case being likewise a week. After this the skins are taken out and dried in the ordinary way, when they are fit for currying with the empyreumatic oil which gives this kind of leather the virtues so much desired. In the execution of this part of the work, the ordinary course is followed, fish oil being first used, with the requisite shavings, stretchings, and pommelings, to render it pliable. The leather is then grained by passing it between rollers weighted to the proper degree by levers or some analogous means, and having on their surfaces raised threads parallel to, and intersecting one another, to give the intended grain. After this the skins are dried to the proper degree, and then oil of the birch, or *Russian* oil, is spread over on the flesh side. The color peculiar to this kind of leather is then laid on, and in this state the skins are repeatedly exposed to the rays of the sun, in order to make the color penetrate into the pores; they are then well pommeled and slicked with the *lunette* or circular knife on the beam, and finally worked with a hard brush on the hair side. The red color of Russian leather is produced with alum and a decoction of Brazil and sandal wood, and the black with a solution of sulphate of iron—copperas—and sandal-wood.

In impregnating with the oil, great care is necessary to have the absorption equal; at the same time, too much oil must not be employed, lest it might pass through and stain the grain side. This is especially to be guarded against when operating on small delicate skins; when it is desired to confer some of the properties of Russia leather upon undyed, or Morocco leathers, the quantity of birch oil necessary is very small.

The method of manufacturing the oil of birch in Russia is somewhat rude. The white membranous matter of the bark of the tree, deprived as much as possible of woody fibre, is introduced into an iron vessel of suitable dimensions till the latter is full, when the cover, of an exterior convex shape, is fixed on. From the middle of this lid an iron tube issues, and enters to about three-fourths of the depth of another iron receptacle placed over the former. The edges of both vessels are well bolted and screwed together, and the whole inverted, so that that charged with the bark is uppermost, and the empty one beneath. In order to condense the oil as much as possible, the empty receptacle is buried in the ground to keep it cool; the top one is then secured by a coating of cement made of clay and sand, and when dry, surrounded with a wooden fire till it is raised to a red heat, which is continued till the distillation is completed. When the two vessels are detached, the upper one is found to contain a light friable charcoal, and that serving as a condenser, a brown oily empyreumatic liquid, possessing a very strong odor, some tar, and pyroligneous acid. The product, being depurated from tar and acid, is retained in well-closed vessels for the use of the currier. In France, the bark is distilled in copper vessels, and the heavy oil condensed in a tube passing through water, or an ordinary worm. About six per cent. of the bark passes over, but the oil, which is highly colored, is not very abundant; by rectification, however, it can be obtained almost colorless, in which state it is better adapted for oiling fine white leather than the original product, as it does not leave any stains.

It appears from the experiments of CHEVREUL, PAYEN, and CHEVALIER, that the principle to which the above oil owes its odor and other qualities, is a white pulverulent substance soluble in alcohol, which they call *betulin;* it is volatilized by heat, and condenses into crystalline needles ; thrown upon live coals, it gives off thick white vapors similar to those emitted by Russia leather under similar circumstances, but more agreeable.

Hungarian Leather.—By the method long known and practised in Hungary, and latterly in France and other countries, leather is prepared in a rapid way, and without the aid of tannin—mineral salts being substituted together with other agents. The substance most generally resorted to for combining with and preserving the tissue of the skin, in other words, for converting the latter into leather, is sub-chloride of aluminum, produced by the decomposition of ordinary alum by common salt. This preserves the skin ; and another kind of tanning process, with oil or tallow, gives the leather suppleness, and prevents it from forming a hard body. In this manufacture, the influence of the season, air, or other agents which affect the labors of the ordinary tanner are not felt, in consequence of the brief time it occupies, and the nature of the process. The requirements for carrying on the business are fewer and more simple than those of the ordinary tanner. They consist of a shed erected on the banks of a stream, wherein the beams for pairing, fleshing, and unhairing are arranged, and the knives, scraping stones, and other tools kept. A boiler and furnace for preparing the alum liquor is fitted up in one corner, besides which are two larger tubs for immersing the skins, together with a number of smaller ones. The other division of the factory, where the oiling is done, consists of a room six and a half feet high, by sixteen and a half square, capable of being rendered perfectly tight. One corner of this chamber is occupied with the furnace, over which is placed a copper pan capable of containing one hundred and eighty pounds of tallow ; the sides are occupied by tables, whereon the skins are greased ; the centre has a stone slab three feet and a quarter square, and on this an iron grating is fixed, whereon charcoal is burned for the purpose of flaming or heating the hides, as will be mentioned afterwards. The upper part is furnished with poles for hanging the skins on.

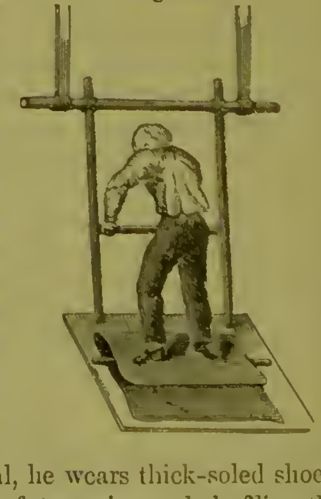
In tanning or preparing Hungarian leather, the principal preliminary processes are analogous to those already described, only that instead of liming for the depilation, the hair is carefully shaved off—that is to say, the skins are well washed, cut in halves, shaved, and steeped for twenty-four hours in the running stream.

The greatest care must be exercised, and the most expert workmen employed for fleshing, paring, and shaving off the hair, lest the skin should be injured , and at best the operation is tedious, so much so, that one man can work no more than a dozen or fifteen skins in a day. The shaving and washing being completed, the hides are passed through the first alum bath, composed of six to seven pounds of alum, and three and a quarter to four and a half pounds of common salt dissolved in eight gallons of water, for every hide of seventy-five to eighty-five pounds weight. After raising the temperature of this solution to about 120°, or a little higher, the hides or sides are arranged in parcels of three or four in each, and deposited in two large tubs already mentioned, the hair side being uppermost.

As much of the liquor as will cover them is now poured in, and a workman stamps or treads them out, passing backwards and forwards till the piece exposed to this treatment is sufficiently worked, after which it is rolled up, and the same operation proceeded with till every one of the parcel has received the proper treading. After this, the partly-spent alum liquor is returned to the boiler ; and as soon as its temperature is raised, another quantity is ladled into the vat, and the pieces of skin tramped out as above. A third and fourth treading is given, using warm liquor each time. after which they are folded up and deposited in a series of small tubs, about two feet high and eight inches in diameter, and the spent alum menstruum poured over them. They remain in these tubs for eight days, or longer in winter, being handled every day, and the liquor freshened. At the end of this time the strips of skin are taken out and shaken, or stretched, to remove creases, and then treated a second time exactly as in the first aluming, save that they are left only twenty-four hours in the small tubs, in contact with the saline water. After taking them out, they are laid one upon another on an inclined plane, in order that as much of the alum liquor as possible may run back into the vat. When thoroughly drained, the ends are pierced at the corners, and wooden rods or laths thrust through : then one of these is laid on cross-beams, and the piece of hide distended permitted to be freely suspended. Here they remain for eighteen hours, and then they are taken down, laid on the floor, and the workman, by folding and stretching, removes the wrinkles and creases ; this done, they are laid one upon another, and left so for two days, then hung up by the laths on the cross beams till thoroughly exsiccated.

The dried skins, before they are fit to receive the oil, must be softened by treading them upon an inclined plane, suspended, as shown in the figure annexed, by upright and cross pieces firmly bound together. The strip of skin is laid doubled on this plane, and a smooth stick placed in the fold, and the workman, laying hold of the cross handrail, tramps upon the skin, and, by a shuffling motion of his feet and body, causes every part of it to be pressed and smoothened by the roller. To render the process more effectual, he wears thick-soled shoes. He continues the work of tramping and shuffling the stick about in the fold of the skin. till the latter becomes as soft and pliant as it is possible to make it. Each strip or piece is thus worked, and subsequently exposed for a short time, to be dried if necessary. After this

Fig. 852.



desiccation, they are again slightly trodden in the same manner as before, to erase any contractions and wrinkles, *et cetera.*

They are now fit to be greased, and, therefore, are submitted to this operation. The boiler, which occupies one corner of the air-tight chamber wherein this work is done, is three-fourths filled with tallow, fish oil, or whatever else is used for saturating the skins, and the whole heated by a fire outside the walls of the apartment. When the temperature stands a little above the melting point, a short-handled mop or dauber is dipped into it, and the fat spread equally in this heated state over the flesh side, after which the strip is turned, and the hair side brushed over with what remains in the dauber. Those which are first greased are laid upon one another, flesh side upwards, successively, till the entire number have been treated. They are allowed to remain for a time, to enable them to absorb the fat as much as possible before *flaming* them. For this purpose, a fire of charcoal is lighted on a grate, constructed on bricks in the centre of the room, and whilst it is being lighted, the workmen, two in number, leave, closing the door tightly after them. As soon as the charcoal is thought to be incandescent, they open the door to allow the carbonic acid to escape, and then enter, and taking the top strip of the pile, each by one end, expose it, flesh side downwards, to the glowing fire, holding it at some distance, and at the same time stretch it in all directions. The first so treated is laid on an adjoining table, and the others as they have passed through the same operation are piled upon it, the whole being covered with cloth as a protection against cold draughts and the unequal effects of the fire. This treatment aids in the absorption of the oil, and the stretching given at the same time improves the product. After an interval of an hour, the hides or sides are deprived of the excess of fat by wiping them. They are then thrown across poles to dry, flesh side outwards. The last exposure gives them a consistency, owing to the combination of the fat with the tissue and the saline matter united to it. The direct rays of the sun and an increased heat are to be avoided in this final airing, as neither is conducive to the improvement of the article. After this airing the sides are weighed, stamped, or marked, and put up for the market.

Hungarian leather prepared in this way, without the intervention of acids or alkalies, fermentation, or other matters and processes that are known to be more or less injurious when making leather with tan, preserves all the tenacity and body of the skin, combined with strength and great suppleness; for which, and for its tractive power, it is much used by saddlers and harness-makers.

TAWED LEATHER.—In the preparation of this kind of leather, the conserving agent resorted to is a subsalt of alumina, just as in the manufacture of Hungarian leather. The skins most generally treated are those of sheep, lambs, and kids, together with a few other light varieties. Generally the preliminaries required are performed in the ordinary way, only the skins being more tender, demand greater vigilance to preserve them from injury. They are well soaked in running water for the purpose of cleansing. If dry, as in many cases, this steeping must be assisted by working or *breaking* them upon the beam with the back of the fleshing knife on the inner side. After another rinsing, the skins are smeared with cream of lime, or a mixture of lime and orpiment, gas lime, *et cetera*, on the flesh side, and then laid together in pairs, the hair side being outwards. According to the efficacy of the depilating agent employed, the time of the slacking of the skins extends from twenty-four hours to several days. However, as soon as it is found that the hair yields, it is separated, not in the usual way, but by plucking it out by sharp pincers. This being done, the skins are smoothened by a roller or some such means; then re-immersed for a short time in a weak lime-vat, from which they are removed to another steep, and left to soak therein for ten to fifteen days, with occasional handlings or examinations. When taken from the last vat, they are ready to be submitted to the bran vat or ferment, similar to those already mentioned, the proportions being forty pounds of bran in twenty gallons of water. In this mixture the skins remain for a period of a fortnight or three weeks in winter, according to the lowness of the temperature; but in summer, when the weather is hot, two or three days suffice to raise them sufficiently.

In any case, as soon as the skins sink in the menstruum—an occurrence which may be hastened by stirring them frequently—the action of the steep is known to be completed, and the skins are taken out and submitted to the first alum or *white bath.* This is composed of a mixture of thirteen to twenty pounds of alum, and three to four and a half pounds of chloride of soda dissolved in boiling water, the solution being afterwards diluted so as to saturate one hundred sheep skins. In summer the proportion of salt is increased, in order to preserve the skins from any injury of a putrefactive nature. The working of the skins is done in parcels, as in the preparation of Hungarian leather, each parcel being passed successively through the bath; after which, the whole are immersed for ten minutes. In some tanneries, instead of simply steeping the skins in the latter bath, the alum liquor is introduced at the proper degree of warmth, together with the skins, into a cylindrical vessel with means for revolving attached, and worked for the necessary time. The intimate contact of the skins with the whole of the liquid in this case promotes, it is said, the combination of the basic aluminous salt with the tissue, much more completely than is done in the other mode. The skins intended to remain white are then put into a paste, made by adding to the alum bath from fifteen to twenty pounds of wheaten flour, with gradual stirring, and the yolks of fifty eggs well whisked, and the whole contents of the bath well blended by brisk stirring. The skins are passed singly through this menstruum, which is about the consistence of honey, and afterwards the whole hundred are immersed, and allowed to remain in it during the night. After this they are taken out, and suspended on poles to dry, and left exposed for this purpose from eight to fifteen days, according to the weather, being occasionally stretched both ways. When sufficiently dry, they are worked upon the *softening iron*, by which process any unevennesses are removed, the whiteness is developed, and the whole uniformly stretched. They are next fixed on hooks, where the stretching goes on—more, however, in the breadth than in the length of the skin—being worked during the period of their thorough desiccation with the stretching iron. In some cases the dried skins are submitted to a polishing process, by rubbing them with pumice and giving the final gloss with a smooth flat-iron.

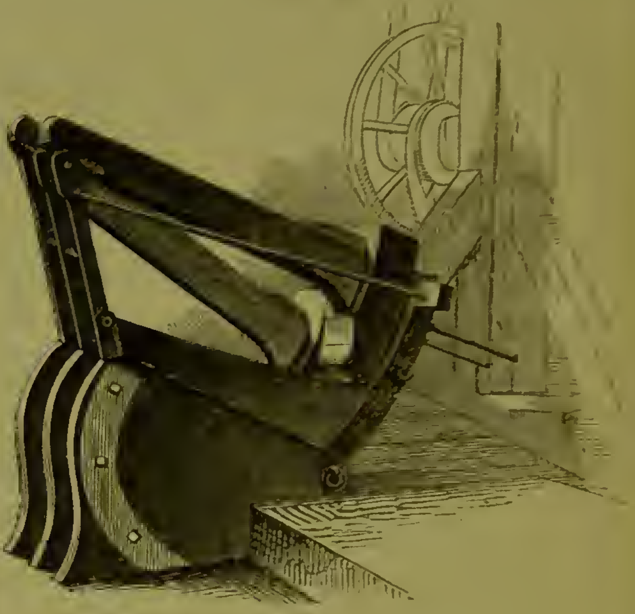
These operations suffice for the preparation of tawed leather, in which the alum salt serves as tan, and the albuminous matter impregnated with it in the farinaceous bath supplies the place of oil or fat in giving greater suppleness and impermeability to the preparation than it otherwise would possess. Skins are frequently tanned by this process, with the hair retained and dyed. All the operations necessary in this case are the same as have been just detailed, with the exception of those that aim at the removal or softening of the hair, which are carefully guarded against. When dyed rugs are prepared, the wool is colored, previous to the commencement of the tawing, by any of the ordinary methods.

Tawed leather is occasionally colored. The tinctorial matter, whatever it may be, is laid on the grain side in a moistened state and while the skin is yet damp, and worked into it by means of a stretcher, after which treatment the polishing and smoothing take place.

Oil or Chamois Leather.—This article takes its name from the skins of the *chamois*; but, although the term is still retained, those of sheep, deer, lambs, and the thin portion of split hides and skins, are now converted into it. It is different from any of the varieties hitherto described, because neither tannin nor mineral matters enter into its formation; the conservation being entirely effected by means of oils and fats. Further, the finest, as well as the coarsest quality known as *wash-leather*, receive precisely the same treatment, and consequently the difference they present is owing to the circumstance, that the finest skins are chosen for the former, whilst the inferior ones are made into the latter. In the last, sixteenth, and earlier centuries, the trade in chamois leather was much more considerable than at present; because, in those periods, it was extensively used for clothing, particularly in the armies. It is now, however, abandoned for this purpose, in consequence of its permeability, owing to which it readily absorbed moisture, and parted with it but slowly; qualities which kept the wearer in continual danger of cold and rheumatic complaints.

In the manufacture of chamois leather the skins are prepared by passing through the lime vats, scraping on the horse, *et cetera*, in the ordinary way; and when these preliminaries are effected, and the lime removed in the lactic acid or bran vat, as much as possible, they are subjected to the *frizing* operation. This consists in rubbing them with pumice-stone, or the blunt end of a round knife, till the grain is entirely removed, the surface softened, and an equal thickness obtained throughout. After this the skins are squeezed or pressed, in order to remove as much water as possible. With this view they are placed in the trough of a fulling mill, such as is represented in Fig. 353, after the large excess of water has been expressed, and are there subjected to the action of the wooden hammers till they become nearly dry. When this happens, they are spread out on the table to receive the first charge of oil. That employed is usually cod oil, although any kind of animal oil is made to answer. When this has been sprinkled upon them, they are rolled up in bundles of four each, and then submitted to the action of the mill for a period varying from two to four hours, or until the oil has united or become absorbed in the pores of the skins. They are then taken out, unfolded, and exposed to dry for a short time; then a second oiling is given, followed by a fulling. It is necessary to repeat these operations several times, to insure the proper saturation of the skin fibre. However long the action of the fulling mill is continued, it is necessary to bring the aid of heat into requisition before the combination of the fatty matter with the skin is completed. Heat is applied generally by suspending the skins in a close chamber, furnished with steam pipes, or warmed with a stove to the proper degree. It is supposed that during this heating a fermentative change takes place, by which certain deleterious matters are destroyed, and the skin is afterwards better able to resist putrefaction, in addition to the more complete saturation of every part.

Fig. 353.



The greater dilution of the oil by the increased temperature of the stove-room causes part of it to exude on the surface, and this must be removed by immersing the skins in a wash or bath, made with soda or potassa in water, and of such density as will not dissolve the fibrous tissue. The skins are steeped for an hour, and handled in this bath, after which they are wrung at the peg and dried. To give the finish, the leather is worked with the stretcher on the table, then on the horse, and lastly, passed between rollers to give it the polish. The buff-color which generally, though not always, distinguishes chamois leather, is given by immersing the oiled skins in an infusion of oak bark, and afterwards wringing, drying, *et cetera*. The tannin reacts here as a dye, and not as a tanning agent.

For supplanting the hand labor in *frizing* and other operations, NISBET has patented machinery by which rough bodies and knives, mounted on revolving cylinders, are made to rub against the skin. By this means a regularity in the thickness and texture of the skins is obtained, which could hardly be gained by hand unless more than ordinary attention were bestowed upon the work, while the time is curtailed to one-tenth of that required by the old method.

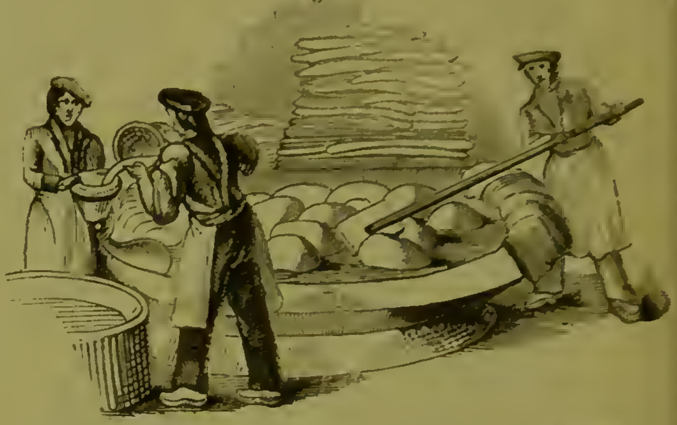
MOROCCO LEATHER.—*Maroquin*, French; *Saffian*, German.—Before the eighteenth century all morocco leather was imported from the Levant; but of the way in which it was prepared, nothing was publicly known till the account of GRANGER appeared in 1735. About the middle of the last century a manufactory was established at Paris, the first of its kind, in the Faubourg St. Antoine; this in a few years was followed by another; and from the impetus given by an increased demand, the trade continued to extend until, at the present time, there are several manufacturers of this article to be found in the different countries of Europe, and in the United States of America. Morocco is commonly known as a colored leather, having an indented or wrinkled fibrous appearance. The genuine or true variety is made from goat skins; but another kind, known as *imitation morocco*, is manufactured from sheep and lamb skins. As stated in the introduction, in connection with the subject of skins, the best kinds for this purpose come from Switzerland; but the English manufacturer draws upon other countries for his supply, such as Germany, Memel, Mogadore, East Indies, Cape of Good Hope, and several others. Compared with sheep skins, those of the goat have a closeness of fibre, a body, and strength that render them much superior in point of appearance and durability. In France, the Spanish goat skins are highly esteemed, and, consequently, a good many are imported from that country.

The skins usually come into the tannery in the dried state; and the operations required to render them as soft and pliable as fresh ones, and likewise to deprive them of epidermis, hair, and particles of flesh, are so similar to those already described in connection with the ordinary tanning processes, that a very brief account of the method of treatment will be sufficient. The dried skins are first immersed in water till they are sufficiently softened, and after this in a fermentable bath of a weak nature, such as has been used for a previous operation. Here the softening is considerably assisted; but it is necessary to watch its effects with much attention, lest it might be productive of injury to the skins. When it is thought they have acquired the proper degree of pliancy, they are worked on the flesh side with the disc or circular knife, to separate the fatty and fleshy matters, and likewise to remove the creases produced in the drying. This done, they are next submitted to the depilating agents, which consist of a number of solutions of lime, increasing in strength from the first to the last. Scarcely any difference exists between this part of the process and that which is followed in tanning upper-leather; but as the retention of lime or fatty matters is still more objectionable in skins intended for morocco, owing to such matters being liable to produce spots or stains in the color applied at a future stage, greater attention and labor are required for their complete removal; hence after the unhairing, the fleshing, and paring of the head and leg parts, and the short steeping in lime-water which is usually given after this, the trimmed skins are introduced into a wooden cylinder moving upon an axis, and having interiorly a number of wooden pegs rounded at the end. This fulling machine is half filled with clean water, and, being charged with as many skins as it will conveniently hold, it is set in motion. By the action of the pegs and the movement of the skins and liquid, a considerable quantity of the lime is separated, the water of the cylinder being frequently renewed. To complete the depuration from lime, it is necessary to submit the skins to a bath of fermented bran or flour disseminated in water, or to one formed of dogs', pigeons', or pen-fowls' excrements, and called as usual the *bate* or *pure*. After being in one or other of these, as the case may be, from twelve to twenty-four hours, according to the strength and temperature, they are taken out and scraped on the beam on both the flesh and grain side, and examined for the purpose of rejecting those which are inferior or in any way damaged. In some instances, instead of the bran vat or *bate*, a solution of honey or a decoction of figs has been employed, together with a little salt, to steep the limed and unhaired skins in, on the principle of TURNBULL'S patent, when the saccharine matter enters into a readily-soluble combination with the lime, and washes out with facility. In either case the more perfect skins which are set aside for the better quality of morocco, are prepared for the operation of dyeing, which with them generally takes place before the tanning, whilst the second and third qualities are colored after the tanning is executed.

Red Morocco.—The perfect skins are placed together two by two, so that the parts of one correspond with those of the other, the flesh side of each being inwards, and then sewed round the edges sufficiently close to retain the air, which is afterwards blown into them so as to swell them into a kind of bag. In this state, on being plunged into the mordanting liquor, only the surface destined to be dyed takes up the substance of the mordant, and consequently of the dye afterwards, and therefore no waste is incurred. The mordants are generally alum, chloride of tin, wine-stone, or such substances; but the tin-salt gives the finest shade of color. The mordant liquor of either of these, sufficiently diluted and warm, is put into a suitable vat or vessel, and the swollen skins immersed for a few minutes in it, then withdrawn and allowed to drain where the drippings may flow back to the vat. Afterwards they are worked on the beam with the view of giving them a grain, and expelling the excess of liquor more completely. This treatment prepares them for the dye, which is usually cochineal, as it gives the brightest color of any. For each dozen of skins from twelve ounces, or less, to sixteen is taken, according to the size. It is finely powdered, and suspended in water to which cream of tartar or some alum has been added. The whole is then boiled for some time in a copper, filtered through a fine cloth, and divided into two equal portions to give two successive immersions. The skins sewed up thoroughly are placed in the tun with half of the dye liquor, and well agitated for about half an hour, after which time the liquor is replaced by the second portion, and the motion of the contents prolonged for a further half hour, when the dyeing will be completed. The skins are now taken out and submitted to the tanning operations, which are the same as will be presently described. Finally, the sewing is ripped; the skins—now tanned leather — well rinsed in fresh water, worked on the beam to render them supple and remove creases, dried, pommelled, slickered, and grained in the ordinary way. Sometimes the dye is brightened by passing a sponge saturated with a solution of carmine in ammonia over it, after the partial drying that follows the tanning and rinsing, *et cetera.* Also the skins are wetted with a decoction of saffron, in order to obtain a shade of color approaching to scarlet.

Morocco of other shades of Color.—Morocco leather of other colors is tanned previous to fixing the dye upon it. After the depilation and *bating*, or *branning*, as the case may be, the pelts are placed in a revolving cylinder with the tanning agent, which is always sumac, and a proper quantity of water slightly heated, and the agitation kept up for some time, by means of connecting or driving bands, and drums on the axis of the cylinder, and on the main or other shaft of the engine. The first tanning is given with sumac, partly or half reduced, and suspended in water, so as to form a thickish paste, and finished by substituting a new bath of fresh sumac; the motion of the cylinder being maintained whilst the skins and tanning agent are in contact. With this method, the formation of leather is very rapid, requiring only twenty-four hours. The tanned skins are now removed from the cylinder, rinsed, so as to clean them from the sumac, and exposed in the drying-room; and when the assimilated water is removed, they may be stored, or at once submitted to the process of dyeing, according to the requirements of the tanner. Another method is also much followed, as well with skins that have been dyed red as with those not so treated; it consists in employing a decoction, or *ooze* of sumac, and filling the skins with it, they being sewed two and two together for this purpose, having the flesh sides inwards, as already detailed. A quantity of powdered sumac is then introduced into each through the aperture, and afterwards a decoction of the tan; the opening is now secured, and the bags thus formed are deposited in a large tun, likewise containing a solution of sumac tan, as represented in Fig. 354, where they are floated and moved about, so as to expose every part of the skin to the action of the tanning agent. When the solution and tan in the leather bags are supposed to be exhausted, the bags are taken out and laid on the rack adjoining the tun, where they drain for some time; they are again filled with the strong solution, floated and moved about in the large tub as before, till the tannin has entered into combination. They are now removed from the tun, placed to drain, till the contained liquor is emptied into the tun, ripped, and cleaned from the debris and impurities of the tanning material by thorough washing in cold water. Any wrinkles are removed by working on the beam before exposing them on the drying loft. During the desiccation, the skins shrivel so much as to necessitate their immersion in water for some time, or the fulling of them in a machine such as is used for making chamois leather, tepid water being used. After fulling, several workings on the beam are given, as well on the hair as on the flesh side, in order to remove the excess of sumac. One of these workings consists in beating the tanned skin upon a table studded with round-headed pegs, with the view of breaking up the small fibres, which otherwise, by their contraction or expansion, would cause the articles made of this kind of leather to become deformed. They are placed one upon another, flesh side inwards, and stitched round, or indented with a blunt knife round the border, so as to keep them temporarily together, whilst they are being handled in the color-vat, and to prevent the dye being deposited on any other part than the grain side. For all the shades of color, with the exception of blue and black, a steep of Campeachy wood is employed, heated as hot as the hand can bear; this is put into a rectangular vessel, and the two skins laid into it carefully, and pressed and worked, so as to induce the penetration of the liquor, but not to remove them from one another. Several immersions are required with fresh coloring matter, till the proper tint is obtained. Much practice and attention are necessary to immerse and work the skins in the dye-vat, in order to stain them efficiently, and prevent the color running on both sides.

Fig. 354.



Black morocco is prepared by applying with a brush, on the grain side, a solution of sesquiacetate of iron. The azure tint is given by means of the cold indigo-vat, or with Prussian blue; violets and purples are produced by giving two coats of blue, and afterwards passing the skins through a bath of cochineal, the strength of which is regulated according to the shade required; yellows are obtained by working with quercitron root, finely ground and digested to abstract the color; this dye is very brilliant and stable. By modifying the work and multiplying the immersion and baths, any shade intermediate between those described can be obtained.

The dyed skins are now placed on the plate of the hydraulic press, and the excess of dye-stuff expressed, after which they are worked on the beam, to remove creases or wrinkles, and dried; first spontaneously in a current of cold air, and afterwards in a heated atmosphere. Before being perfectly dry, however, they are worked with the knife, slicker, and pommel, as in the operation of currying, whereby they acquire suppleness and equality of substance throughout. They are then well polished, and the peculiar grain of morocco leather given. The latter is done sometimes by hand, but more generally by machinery.

Rollers, having raised parallel straight or diagonal threads, give the indented or wrinkled appearance, which distinguishes this kind of leather. When the skins are merely tanned, as when intended for the shoemaker, and then curried, the operations of the last process are such as are applied to delicate calf skins, only that as the goat skins are so much thinner, much greater care and delicacy of manipulation must be exercised in all cases.

SKIVER AND ROAN.—*Skiver* is a leather prepared from sheep skin and sumac, like imitation morocco, only the skins are split by machinery. In tanning the sections, however, the practice differs from that followed when preparing the morocco leather, inasmuch as the sewing of the skins into bags is omitted, the extreme thinness of that intended for skiver adapting it to combine with the tan more readily when spread out in the ooze. *Roan* is sheep skin tanned like morocco leather in all its details, but wanting the grain given to the latter by the grooved rollers in the finishing processes.

Before closing this article, it may be proper to give a short notice of two other materials, which, though not leather in the proper sense of the term, are nevertheless analogous to it; these are Parchment and Shagreen. Both are prepared from the same kinds of skin, but generally the stronger and coarser kinds are reserved for the latter.

PARCHMENT.—This article, undoubtedly of Eastern origin, is said to be the invention of EUMENES, king of Pergamus, in Asiatic Turkey, who reigned about 200 years before CHRIST. It was much used as a substitute for the papyrus, owing to its durability; and even at the present time it is the article in general use for valuable writings, such as deeds, wills, and the like. The fine parchment used for such purposes is manufactured from the skins of young calves, kids, still-born lambs, sheep, and goats; but when intended for coarser purposes, such as drum-heads and the like, those of older calves, wolves, asses, and *he*-goats, are taken. Soaking or fulling, liming till the hair is softened, scraping, fleshing, and washing, prepare the skins for the process of conversion into parchment, properly so called. It consists firstly in stretching the cleaned pelt upon a circular hoop, or more generally upon a stout rectangular frame, furnished with holes, pins, and screws, or skewers and cords, for exerting any required tension. This machine is usually fixed against the wall of the building, for the purpose of facilitating the scraping and rubbing of the drawn skin, after it has been sufficiently extended by the pins and skewers. The preliminary scraping effected with a double-edged semicircular knife, formerly referred to, removes adhering flesh and other extraneous matter. After the fleshing, the frame is turned, and the grain side carefully rubbed with the blunt edge of the knife, to throw off the exudations of dirt and moisture. Then follows the *grinding*, which consists in sprinkling the flesh side with finely-powdered chalk, or slaked lime, and rubbing with a piece of pumice-stone, the face of which is previously flattened upon a sandstone. By this operation, a further portion of the assimilated moisture is taken up. A slight rubbing with the pumice-stone is then given on the grain, but no lime is used, and afterwards the drying is allowed to go on gradually out of the sun's rays. In cold weather, the freezing of the moisture in the skin would be injurious; and is, therefore, carefully guarded against by keeping the temperature of the room above 32°, or by protecting the skins with cloths. Towards the completion of the desiccation, the skewers are further tightened. Finally the white appearance given by the lime is removed by careful rubbing with the woolly side of a lamb skin. Should grease stains be now detected, it is necessary to immerse the skin anew in a lime-pit for eight or ten days, to remove them; this induces the formation of a lime soap with the fatty matter, and consequently the deletion of the spots. The pelt is again stretched on the *horse* or frame, and dried, and then transferred to the *scraper*, who mounts it upon a frame like the last, the tail end downwards, and stretches it with cords only, on a support of well-extended crude calf-skin. Here it is carefully pared with a larger and sharper knife, but similar to the one used for *fleshing*, to remove inequalities, and then scraped on the grain or outside, till a perfectly even, smooth surface is given. Whatever is wanting in this operation, is remedied by a further rubbing with a very fine-faced piece of pumice-stone on a cushioned support. Any defects in the skin, such as holes and the like, are removed by carefully paring round the edges of the injured part, and tastefully patching suitable pieces on with gum-water.

The green color of parchment is given by spreading with a brush a solution, made with thirty parts of crystallised acetate of copper and eight of bitartrate of potassa in five hundred of rain or distilled water, four parts of nitric acid being added to the mixture when cold. It is necessary to moisten the skin before applying this dye. Finally, the lustre is given by rubbing the surface with a solution of albumen or gum arabic.

SHAGREEN.—The article known under this title is very analagous in its nature to parchment, and consequently is not a true leather. Like parchment, it was originally an Eastern preparation, and is still principally obtained from Astracan and Asiatic Russia. From the accounts obtained of the manufacture, it appears that only the hides of horses, asses, and camels, are appropriated to its production, and of these only the small strip from the crupper along the chine to the neck is used.

The strips, cut out of the proper size, are steeped in water till the hair softens and gives readily, when it is removed by scraping; they are again steeped and worked by the *flesher*, till all matter extraneous to the skin is separated, and the skin itself is reduced to the proper thinness. They are now mounted on the *herse*, or horse, and stretched thoroughly, being occasionally moistened to favor the stretching.

As soon as this has been carried sufficiently far, the strips of skin are placed on the floor and covered on the grain side with the seeds of the *alabuta* or goosefoot—*chenopodium album*. A covering of felt is then laid on, and the seeds are pressed into the skin by trampling on them, or by the use of mechanical pressure. The skins, still bound in the frames, are then dried, till the seeds begin to drop, when the latter are shaken off. At this stage the skins appear dry, horny, and deeply indented. They are next placed on a padded horse, and shaved till the indentations caused by the seeds become very shallow and of uniform depth, after which they are steeped in water and then in a hot alkaline lye, and piled one upon another whilst in a hot moist state. During the time they are so left, the compressed parts swell out, forming as it were embossed balls on the skin, and thus constitute the peculiar appearance of this preparation. Shagreen is dyed of various colors; red is obtained with a decoction of cochineal, in the same way as morocco; blue by the cold indigo vat; black, by steeping the skin, or brushing on the side intended for the dye, a solution of tannin, and afterwards one of sulphate of iron—copperas; and green, by moistening with a dense solution of chloride of ammonium—sal-ammoniac—and sprinkling the part so moistened with copper turnings and rolling up the strip, keeping the grain side inwards. The ammoniacal salt dissolves a portion of the metal and forms a subsalt with it, which enters into combination with the skin, and gives a bright hue. To finish the article, the dyed strips are carefully greased and worked in hot water, then rubbed with blunt tools and dried.

Shagreen of an inferior quality has been made from sheep, goat, horse, and even fish skins; the treatment they receive is analagous to that already described, but for the most part, where the skin is weak, a slight tanning is allowed before shaving, and the skin is stretched more in the direction of its length than crosswise. The grain is given by pressing the prepared skin on warm copper plates, engraved so as to imitate the appearance of the genuine shagreen.

In preparing this account of the leather manufacture, much of the information, besides what has been derived from private sources, has been obtained from Doctor MORFIT's able work on Tanning, KNAPP's Technology, SCHUBART, DUMAS, PARNELL, SULLIVAN, the Catalogue of the Irish Industrial Exhibition, and other authorities.

STATISTICS.—The following table expresses the imported quantities of the principal tanning materials in 1849 in hundredweights:—

	Tanning bark, *et cetera.*	Terra Japonica.	Sumach.	Valonia.
Belgium,	141,392	—	140	—
Holland,	114,180	—	—	—
East Indian empire,	—	169,140	—	—
Naples and Sicily,	1,166	—	218,380	—
Turkey,	—	—	—	296,000
America,	42,318	—	—	—
Australian territories,	—	—	29,840	15,820
Morocco,	27,619	—	—	—
Norway,	12,784	—	—	—
Spain,	9,594	—	440	—
Tuscany,	9,931	—	20	4,320
Australia,	4,563	—	—	—
Syria,	—	—	—	4.280
Greece,	—	—	—	10.480
Miscellaneous,	5,035	—	2,980	2,520
Total,	368,582	169,140	251,800	333,420

MAGNESIA.—English and French; *Talkerde*, *Bittererde*—German.—This is one of the primitive earths, and was first discovered by Sir HUMPHREY DAVY to be the oxide of a metal which he designated magnesium, and which LIEBIG has proposed to prepare by calcining a mixture consisting of chloride of magnesium and chloride of ammonium. Very great precautions are requisite in this method, and especially the most complete desiccation. On the mixture being dried, the ammoniacal salt begins to volatilize; the mass is to be pulverized and reheated, in order to expel the last traces of moisture. The difficulties which this operation presents, and the errors to which it frequently gives rise, induced BUNSEN to seek for a less doubtful and convenient method of procuring this singular metal. Now, the chloride of magnesium is decomposed with the utmost facility by the galvanic current when it is liquefied by heat. A few elements of a Bunsen's battery suffice for obtaining in a short time several grammes of product.

Take a platinum crucible equally divided by a vertical diaphragm for half the height of the vessel; this diaphragm is necessary for the protection of the magnesium, in proportion as it is released from the action of the chlorine, which is liberated at the positive pole of the battery. The crucible is closed with plugs of fire-clay, traversed by two charcoal stems constructed as for batteries. These stems form the poles; that which corresponds to the negative pole is hollowed with cavities or channels for the purpose of retaining the magnesium, which, if this precaution were omitted, would float on the bath of fused chloride of magnesium, in which it would be burned.

Magnesium is silvery white, has a crystalline and sometimes fibrous fracture, is malleable, ductile, and fusible at a dull red heat; it is sufficiently hard, however, to work under the file and chisel. Its specific gravity, as determined by various experimenters, ranges from 1·87 to 2·24. Dry air produces no action upon it, but in damp it is tarnished, and covered with a layer of magnesia. At a red heat it consumes with a brilliant white flame. Cold water is only very gradually and with difficulty decomposed by this metal, which is quickly dissolved in acidulated water. Finally, it ignites when brought into contact with hydrochloric acid, whilst concentrated sulphuric acid dissolves it with difficulty.

Oxide of magnesium, or *magnesia*, is a fine, light, white powder, void of taste or smell. It requires for complete solution more than five thousand parts of cold, and *thirty-six thousand* parts of boiling water. Its specific gravity is 2·30. It is fusible only by the heat of the oxyhydrogen blow-pipe. Magnesia changes the purple infusion of red cabbage to a bright green. It attracts carbonic acid very slowly from the air. Its equivalent is 20, and its composition as under:—

		Centesimally.
1 Eq. of magnesium, ...	12	60·00
1 Eq. of oxygen, ...	8	40·00
1 Eq. oxide of magnesium,.....	20	100·00

This oxide occurs in nature as carbonate, forming immense masses of rock in various parts of the globe; also associated with carbonate of lime under the forms of dolomite and magnesian limestone; and as sulphate of magnesia—Epsom salts—occurring in many saline springs.

It is best obtained pure by heating the carbonate to redness; but it is also procured by precipitating with potassa or soda the sulphate, filtering and well edulcorating the deposit with distilled water.

Carbonate of potassa or soda causes a precipitate in solution of magnesia; but carbonate and sesquicarbonate of ammonia, owing to the formation of a soluble double salt, gives only a partial precipitate; and, for the same reason, oxalate of ammonia does not occasion any turbidity in liquids containing magnesia. By this last character the earth is separated from lime. The most delicate test for magnesia in a solution is to add, first, carbonate of ammonia, then phosphate of soda—$2\ NaO, HO, PO_5$—which forms an insoluble double phosphate of magnesia and ammonia—$2\ MgO, NH_4O, PO_5$—in the form of a dense crystalline powder. It will be at once seen, that in the above change the ammonia merely replaces the water in the phosphate of soda. The salts of magnesia are isomorphous with those of oxide of zinc.

Physiological Effects.—When taken inwardly, magnesia neutralizes the free acids contained in the stomach and intestines, and forms therewith soluble salts.

As an *antacid* it is as efficacious as the alkalies, while it has an advantage over them in being less irritant and not caustic, and thereby is not apt to occasion any derangement of the digestive organs. It may be employed to neutralize acids introduced into the stomach—as in cases of poisoning by the mineral acids—or to prevent the excessive formation of, or to neutralize when formed, acid of the animal economy. Thus it is administered to relieve heartburn, arising from, or connected with, the secretion of an abnormal quantity of acid by the stomach; its efficiency is best seen in persons of a gouty or rheumatic diathesis, in which the urine contains excess of uric acid. It relieves the headache to which such individuals are not unfrequently subject. It is most efficacious in diminishing the quantity of uric acid in the urine in calculous complaints; and, according to BRANDE, it is sometimes effectual where the alkalies have failed.

As a laxative, magnesia is much employed in the treatment of diseases of children. It is tasteless, mild in its operation, and antacid—qualities which render it most valuable as an infant's purgative. Independently of these, HUFELAND ascribes to it a specific property of diminishing gastro-intestinal irritation by a directly sedative influence.

As a purgative, the dose for adults is from a scruple to a drachm; for infants, from two to ten grains. As an antacid, the dose is from ten to thirty grains twice a day. It is conveniently given in milk. Magnesia has been used with success as an antidote to arsenic. —*Pereira.*

The Editor will now describe cursorily those salts of magnesia which are of importance, and which are much used in the arts.

SULPHATE OF MAGNESIA..—This salt is found in certain mineral springs, as those of Seidlitz, Leydschutz, Egra, and formerly Epsom, in Surrey, whence the name *Epsom salts.* Dr. GREW first obtained it from the Epsom waters. It has had a variety of names, such as *bitter purging salt*, *sal anglicum*, *sal seidlitzeuse*, *sal catharticum*, and *vitriolated magnesia.* At the Lymington Salt Works, says PEREIRA, it is called *physical salt*, to distinguish it from common salt. Its presence in the above-named springs appears to proceed from the reaction of the sulphate of lime, held in solution, upon the magnesian limestone of the soil.

Sulphate of magnesia is also obtained by the action of sulphuric acid upon calcareous rocks rich in carbonate of magnesia, such as *dolomite.* The compound is calcined, and reduced to powder by being aspersed with water; it is then diffused through water, and sulphuric acid is added: sulphate of lime and sulphate of magnesia are formed, the one barely soluble in water, and the other very much so; consequently, they are readily separated.

Epsom salts are also extensively made from the bittern or mother-liquor remaining after the evaporation of sea water, and the separation of the chloride of sodium therefrom.

At Lymington, in Hampshire, sulphate of magnesia is manufactured from bittern during the winter months. The liquor is boiled for some hours in the pans used during the summer for the preparation of chloride of sodium. During the ebullition, some chloride of sodium deposits. The lighter impurities are separated by skimming, and the strong solution is removed into wooden refrigerators, where, in a day, one eighth part of crystals of sulphate, called *single Epsom salts*, or *singles*, are deposited. These are drained, dissolved, and recrystallized; they are then termed *double Epsom salts*, or simply *doubles.*

At Monte della Guardia, near Genoa, sulphate of magnesia is prepared from schistose minerals containing sulphur, magnesia, copper, and iron. PEREIRA states that the ores, after roasting, are converted into sulphates by moistening, *et cetera.* They are then lixiviated, and the solution is deprived, first of copper by refuse iron, and afterwards of iron by lime. At Baltimore, sulphate of magnesia is procured from the silicious hydrate of magnesia, or *marmolite*, by reducing the mineral to powder, saturating with sulphuric acid, and calcining the dried mass to sesquioxidise the iron. It is then redissolved in water, heated with sulphide of calcium to remove the remaining iron, and crystallized. By a second crystallization it is obtained nearly pure.

A very large quantity of sulphate of magnesia is manufactured at Newcastle-upon-Tyne. It is made from magnesian limestone, calcined and washed to separate the lime, then adding sulphuric acid, *et cetera.* Another mode is by calcining rough Epsom salts along with magnesia.

From Magnesian Limestone.—In England, says KNAPP, the sulphate is sometimes manufactured directly from magnesian limestone and sulphuric acid, in conjunction with other products. The carbonic acid produced by the action of the sulphuric acid is employed in the manufacture of bicarbonate of soda, while the mixed sulphate of lime and magnesia are thrown into large wooden vessels, fitted with a false bottom. Water is now poured upon the thick mass, and drawn through by the action of a pair of pumps, worked from an engine shaft in any convenient manner. In this way, the whole of the sulphate of magnesia is extracted with the least expenditure of water; and the solution, after being pumped into a reservoir, is allowed to filter through layers of sandstone and charcoal, to render it clear and bright. The menstruum is now concentrated by evaporation, and made to crystallize as rapidly as possible, in shallow wooden troughs lined with lead, in order that the crystals may be as small as possible, to meet the prejudice of the trade in this respect. The sulphate of lime left on the filter or false bottom is worked up in the manufacture of Venetian red.

The process, however, which is more generally pursued is as follows:—

Magnesian limestone is calcined in an ordinary lime-kiln, and repeatedly washed with water to remove as much of the lime as possible. The extent to which this is carried may be inferred from the following analyses, by RICHARDSON, of a sample of lime in its natural state, and after it had been calcined and washed:—

NATURAL.

Carbonic acid, *et cetera,*	47·12
Lime,	27·49
Magnesia,	22·22
Insoluble matter, alumina, *et cetera,*	3·17
	100·00

WASHED.

Water, *et cetera,*	32·51
Lime,	7·34
Magnesia,	44·41
Insoluble matter, alumina, *et cetera,*	15·74
	100·00

The limestone selected by the manufacturer for this purpose is soft, and similar to that known as *flexible;* such samples as have the appearance shown in the engraving—Fig. 354—do not usually contain so much magnesia.

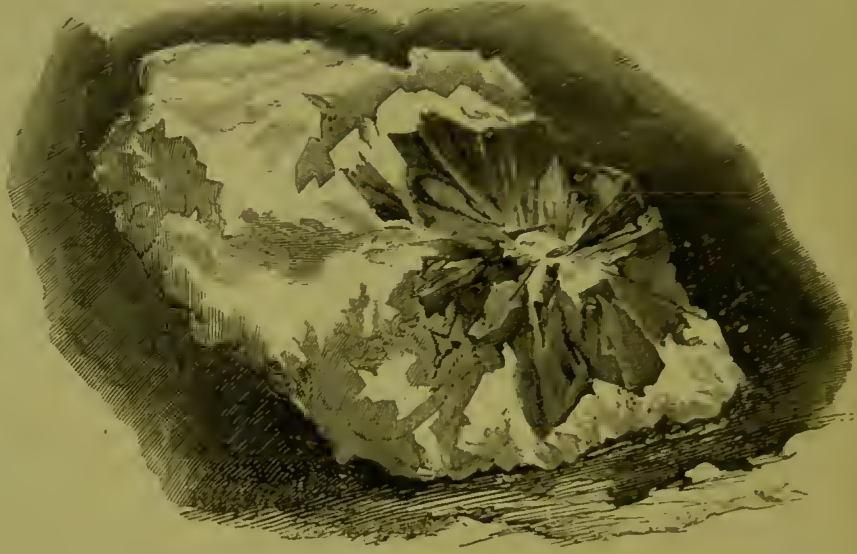


Fig. 354.

From Refuse Alum Liquors.—In the manufacture of alum as conducted near Whitby, the *salts' mothers,* according to RICHARDSON, contain in the gallon:—

	Grains.
Sulphuric acid,	2697·61
Sulphate of magnesia,	8190·40
Sulphate of alumina,	852·24
Sulphate of potassa,	3693·32
Sulphate of manganese,	106·06
Sulphate of nickel and cobalt,	traces
Sulphate of iron,	3026·67
	19286 30

Which, by crystallization, produces a crude sulphate of magnesia, called Rough Epsoms, and having the following composition:—

Sulphuric acid,	32·26
Magnesia,	15·35
Protoxide of iron,	1·73
Oxides of nickel and cobalt,	0·12
Lime,	0·09
Alumina,	1·33
Potassa,	0·83
Water,	48·29
	100·00

These rough Epsoms are mixed with the magnesian lime in such proportions that all the sulphuric acid, except that in combination with the potassa and magnesia, is taken up by the free alkaline earths. The mixture is then calcined in an ordinary reverberatory, at a dull red heat, which assists the transfer of the sulphuric acid, and raises the metals to a higher degree of oxidation, thereby insuring their insolubility. The calcined product is afterwards thrown into a large circular cistern, filled with water, and in which a pair of edge-stones are made to revolve by suitable machinery. By this arrangement, the large pieces are ground to powder, while the agitation produced by the motion of the edge-stones facilitates the solution of the Epsom salt.

The sulphate of magnesia liquor is subsequently clarified in the manner previously described, and crystallized in the usual hollow pans. When the liquid has drained off from the crystals, they are removed to a stove, and exsiccated at a low temperature. In this dry state, they are thrown into a species of sieve or temse, which reduces still further the size of the crystals, and renders the whole of a more uniform appearance.

From Native Carbonate of Magnesia.—Mr. Chance has lately imported a very pure natural carbonate of magnesia from the Mediterranean, to which he adds sulphuric acid, and proceeds in the usual way for the production of the sulphate; and having, it is understood, secured the entire produce of the mine, he is likely to become a formidable competitor to the other manufacturers.

Another article which is manufactured to some extent, requires a passing notice, namely, the salt termed *Mock Epsoms*, which is simply sulphate of soda crystallized very rapidly in shallow vessels, for the purpose of adulterating the genuine article.

The sulphate of magnesia crystallizes in right prisms, which at 60° are soluble in their own weight of water. When exposed to the air, they effloresce, and are reduced to powder. The intensely bitter taste of this salt is well-known. It is composed of,—

	Centesimally.
Magnesia,	16·26
Sulphuric acid,	32·52
Water,	51·22
	100·00

Mr. Alexander S. Stevenson informs the Editor that about two thousand tons a-year are made in Great Britain, and of this quantity the Jarrow Chemical Company of South Shields produce one half.

Hydrated sulphate of magnesia, $\text{MgO}, \text{SO}_3 + 7\ \text{HO}$, crystallizes at the ordinary temperature, in four-sided prisms, with reversed dihedral summits or four-sided pyramids. They are doubly refracting, and their density is 1·70. When crystallized at a high temperature, the salt contains only six equivalents of water, and if crystallized below 32°, large crystals are the result, having twelve equivalents of water. If heated to 460°, sulphate of magnesia still retains one equivalent of water, but it becomes anhydrous beyond this degree of heat; hence the Editor represents its composition as follows—$\text{HO}, \text{MgO SO}_3 + 6$ eq. The crystals are soluble in about three ounces weight of water at 60°, and in three-fourths their weight of boiling water—as given by Tomlinson. One hundred parts of water at 32° dissolve 25·76 parts of the anhydrous salt, and for every degree above this temperature, the water takes up 0·26564 parts additional. It is somewhat remarkable that sulphate of magnesia is much more readily dissolved by hydrochloric acid than by water. Sulphate of magnesia is insoluble in alcohol. Pure crystals exposed to the air have a slight tendency to effloresce; the commercial article always deliquesces on account of the presence of more or less chloride of magnesium. Sulphate of soda is often used to adulterate the sulphate of magnesia; the fraud is easily detected by exposing a portion to the blowpipe flame. If any soda be present, the characteristic yellow color appears.

Annexed is the centesimal composition of the officinal Epsom salts :—

		Theory.	Found.
1 Eq. Magnesia,	20	16·26	16·04
1 Eq. Sulphuric acid,	40	32 52	32 53
7 Eqs. Water,	63	51·22	51·43
	123	100·00	100·00

Physiological Effects.—In moderate doses, sulphate of magnesia is a mild and perfectly safe antiphlogistic purgative, which promotes the secretion as well as the peristaltic motion of the alimentary canal. It is very similar in its operation to sulphate of soda, than which it is less likely to nauseate, or otherwise disorder the digestive functions, while it acts somewhat more speedily on the bowels. It does not occasion nausea and griping, like some of the vegetal purgatives, nor has it any tendency to create febrile disorder or inflammatory symptoms; but, on the other hand, has a refrigerant influence: hence it is commonly termed a cooling medicine. In small doses, largely diluted with aqueous fluids, it becomes absorbed, and slightly promotes the action of other emunctories: thus, if the skin be kept cool, and moderate exercise conjoined, it acts as a diuretic. Dr. Christison mentions a case of supposed poisoning, in a boy of ten years old, by two ounces of Epsom salts. The symptoms were, staggering, imperceptible pulse, slow and difficult breathing, extreme debility, and death within ten minutes, without vomiting. More recently, an old man, a confirmed drunkard, was poisoned by imbibing several pints of beer drugged with sulphate of magnesia. He was seized with violent purging, and died within forty-eight hours. The quantity taken was not ascertained, but there is reason to believe the dose was large.

On account of the mildness and general safety of its operation, its ready solubility, and its cheapness, sulphate of magnesia is by far the most commonly employed purgative, both by the public and the profession. The only objection to its use is its bitter and unpleasant taste. To state all the cases in which it is administered would be to enumerate nearly the whole catalogue of known diseases. It must, therefore, be sufficient to mention, that it is excellently well adapted as a purgative for febrile and inflammatory diseases, obstinate constipation, ileus, lead colic, even incarcerated hernia, narcotic poisoning, *et cetera.* It may be used as an antidote in poisoning by the salts of lead and baryta.

As a purgative, it is usually administered in doses of from half an ounce to an ounce and a half; but if taken in the morning, fasting, a smaller dose will suffice. Sulphate of magnesia is extensively used by veterinary surgeons.—*Pereira.*

Carbonate of Magnesia.—This compound is known in the mineral kingdom as *magnesite;* it is found in Piedmont and Moravia, and also in North America, in veins of serpentine, accompanying the native hydrate. It also occurs in combination with carbonate of lime, with which it is isomorphous. Most of the calcareous rocks contain a small quantity of magnesia. In the species of marble called *Dolomite*, which occurs abundantly in the Alps, about forty per cent. consists of carbonate of magnesia; the marble itself is a double carbonate of lime and magnesia, $\text{CaO}, \text{CO}_2 + \text{MgO}, \text{CO}_2$. The magnesian limestone of Derby and Nottingham is generally of a yellowish color; it dissolves less rapidly in dilute hydrochloric acid than the purer limestone, whence the French term it *chaux carbonatée lente.* It affords excellent lime for cements, but is not adapted to agricultural purposes, probably in consequence of the lime remaining so long caustic.

When an alkaline carbonate is poured into a solution of a salt of magnesia, a white gelatinous precipitate is formed, which is a hydrated carbonate of magnesia, or a combination of the hydrate and of the carbonate. The proportions of these two compounds vary according to the quantity of alkaline carbonate employed, the strength of the solutions, and the temperature. This product is made in large quantities in pharmaceutical chemistry, and is the *magnesia alba* of the pharmacopœia. Two kinds, identical in composition, are prepared, namely, the *light* and the *heavy.* For *heavy* magnesia, add one volume of a cold saturated solution of carbonate of soda to a boiling mixture of one volume of a saturated solution of sulphate of magnesia, and three volumes of water; boil until effervescence has ceased, constantly stirring with a spatula; then dilute with boiling water, set aside, pour off the supernatant liquor, and wash the precipitate with hot water on a linen cloth; afterwards dry it by heat in an iron pot. *Light* magnesia is prepared by employing dilute solutions of the sulphate of magnesia and carbonate of soda. If no heat be used, it is apt to be gritty.

A heavy granular magnesia is prepared by separately dissolving twelve parts of sulphate of magnesia, and thirteen parts of crystallized carbonate of soda, in as small a quantity of water as possible, mixing the hot solutions, and washing the precipitate. The light cubes of magnesia are prepared as follows:—A solution of one hundred parts of sulphate of magnesia in one hundred of water, is put into a vat heated by steam; a solution of one hundred and twenty-five parts of crystallized carbonate of soda is quickly stirred into it, and the temperature raised to 176°, to expel carbonic acid, which holds some of the magnesia in solution; the liquor is then decanted off the precipitate, and this is washed three times by subsidence, and decantation with lukewarm water, free from salts of lime. It is then transferred to linen strainers, and allowed to drip from twenty-four to forty-eight hours, and is transferred in a wet state to cubical boxes without bottoms, placed upon a table of plaster or porous stone, which quickly absorbs the water: after some time, the boxes are turned upside down, so as to present the upper side of the magnesia to the absorptive surface: the exsiccation is completed in warm rooms.—*Tomlinson.*

PEREIRA remarks that the *heavy* carbonate of magnesia is a granular substance, and contains no traces of the prismatic crystals observed in the light carbonate. When submitted to microscopic investigation, it is seen to consist of granules of various sizes; the larger ones are highly refractive, globular, and composed of concentric layers of a radiated structure. When examined by the polarising microscope, they are found to possess a doubly refracting structure; and, like the globules of carbonate of lime deposited from the urine of horses and bullocks, show the black cross. When placed over a plate of selenite, and examined by polarised light, the quarters or spaces between the arms of the cross are colored: those next to each other show complementary tints—the alternate ones the same tints. Thus, if the first quarter be green, the third will be green also; but the second and fourth will be red.

The carbonate of magnesia of commerce is likewise obtained in various ways from bittern. It is also separated from magnesian limestone by a process adopted by Mr. PATTISON, which consists in calcining it at a dull red heat, by which only the magnesian carbonate is decomposed; the calcined stone is then diffused through water, and subjected to the action of carbonic acid, under pressure, by which the magnesia alone is dissolved, and is afterwards obtained by rapidly boiling down the solution. It is a beautiful white substance, very light, and without taste or smell. It dissolves in two thousand five hundred parts of cold, and in nine thousand parts of hot water, and is generally composed of—

	Centesimally.
Magnesia,	53·60
Carbonic acid,	41·73
Water,	4·67
	100·00

By passing a current of carbonic acid through a mixture of water and carbonate of magnesia, a clear solution is obtained, which, surcharged with carbonic acid, is a useful preparation that has been extensively advertised under the name of *soluble magnesia,* or *bicarbonate of magnesia.* This compound cannot be obtained in the solid or crystalline form, for the solution gives, by evaporation, oblique rhombic prisms of hydrated carbonate of magnesia, which on being put into cold water are decomposed, carbonate of magnesia being dissolved, and a subcarbonate deposited.—*Tomlinson.*

Citrate of Magnesia.—This is prepared by saturating a solution of citric acid with carbonate of magnesia. It is a white pulverulent insipid salt, very soft to the touch, heavier than magnesia, and when a slight excess of citric acid is present, is dissolved readily by water. Its composition is—$3\ MgO, Ci, HO$, or $3\ MgO, C_{12}\ H_5\ O_{11}, HO$; equivalent weight, 234.

It is a slight and agreeable aperient, and its superiority over other saline deposits consists in its being devoid of any disagreeable taste.

Tartrate of magnesia is obtained in a similar way to the preceding salt, substituting tartaric for the citric acid, and evaporating the solution to dryness at 212°. The resulting crystals consist of $2\ MgO\ T, 8\ HO$, or $2\ MgO, C_8\ H_4\ O_{10} + 8\ HO$. Equivalent weight, 234. This salt has been used with success in painful chronic maladies of the spleen.

Sulphite of Magnesia.—This salt is now largely manufactured in Manchester, and is employed as a disinfectant, *et cetera.* Full particulars with regard to its use are given in Vol. I., page 565.

Steatite or Soap-stone.—This substance, remarks KNAPP, is known also under the more familiar names of Spanish or Venetian chalk, and is composed of silica, magnesia, alumina, oxide of iron, oxide of manganese, and water. It is found in North America, Sala in Sweden, Cornwall, and China. It is employed in polishing articles made of serpentine, marble, sulphate of lime, and plate-glass; it is also sometimes used as a substitute for grease for the axles of carriages. It is further used for sketching in outline on silk, linen, and glass; as crayon; for painting on glass, and for removing stains in woollen and silk goods. It has also been added in some cases to the materials for porcelain, to improve the transparency, but it renders the mass much more brittle. The apparatus employed for the production of chlorine is occasionally manufactured from this material, as it resists the corrosive action of that remarkable gas.

Meerschaum.—Silicate of magnesia, under this name, is employed in manufacturing the celebrated tobacco-pipes; its composition is as follows :—

	Levant. Lychnell.	Madrid Berthier.	Natolia. Thomson.
Silica,..........	60·87	53·80	42·00
Magnesia,......	27·80	23·80	30·50
Lime,..........	—	—	2·30
Alumina,.......	0·09	1·20	2·00
Oxide of iron,...			
Water,.........	11·24	20·00	23·00
Loss,..........	—	1·20	·20
	100·00	100·00	100·00

MEERSCHAUM FROM MOROCCO ANALYSED BY DAMOUR.

Silica,...............................	55·00
Magnesia,............................	28·00
Alumina,.............................	1·20
Oxide of iron,........................	1·40
Lime,................................	1·00
Potassa,.............................	·52
Water,...............................	10·35
Sand,................................	2·50
Loss,................................	·03
	100·00

Asbestos.—This material is of frequent use in the laboratory, and in the manufacture of various articles destined to resist the action of fire, such as lamp-wicks, *et cetera.* Annexed is its composition :—

	Kobell.	Richardson.	Thomson.
Silica,..........	43·50	43·25	40·95
Magnesia,......	40·00	33·85	34·70
Oxide of iron,...	2·08	10·90	10·05
Alumina,.......	·40		1·30
Water,.........	13·80	7·00	12·00
Loss,..........	·22	5·00	1·00
	100·00	100·00	100·00

BRANDE states, that the salts of magnesia are mostly soluble in water, and bitter; they are all soluble in hydrochloric acid; their aqueous solutions are precipitated by potassa and soda, the precipitate being soluble in hydrochloric, nitric, and sulphuric acids, and in hydrochlorate, nitrate, and sulphate of ammonia. Ammonia only throws down part of the magnesia, and forms a double salt, and carbonates of potassa and soda only throw down part of the magnesia, except the solution be heated, when nearly the whole is precipitated. Chloride of ammonium redissolves the deposit, and when previously added to the magnesian solution, no precipitate ensues on adding the alkaline carbonates, unless the liquor be warmed. The bicarbonates of ammonia, potassa, and soda, give no precipitate in magnesian solutions, except the liquor be boiled. Common phosphate of soda only precipitates concentrated magnesia solutions, but if ammonia or carbonate of ammonia be added, the magnesia is thrown down in the form of ammonio-magnesian phosphate. Moistened with nitrate of cobalt, and heated before the blow-pipe, *the magnesian salts give pale rose-colored compounds:* the tint is only distinct on cooling, and never very intense.

The separation of magnesia and lime is a problem of some importance in analytical chemistry, as they often exist together in the same mineral, especially in the varieties of magnesian limestone. PHILLIPS proposes the following process:—To the hydrochloric or nitric solution of lime and magnesia, add sulphate of ammonia in sufficient quantity; evaporate the mixture gradually to dryness, and then heat the residue to redness, till it ceases to lose weight, by the volatilization of the chloride of ammonium or nitrate of ammonia formed. Note the weight of the mixed salt, reduce it to powder, and wash it with a saturated solution of sulphate of lime till all the sulphate of magnesia appears to be dissolved; dry the sulphate of lime left, and by deducting its weight from that of the mixed sulphates, the quantity of magnesia dissolved will appear. Dissolve the two earths in hydrochloric acid in excess, and saturate the acid liquor by ammonia, then add oxalate of ammonia, and collect the precipitated oxalate of lime on a filter; the magnesia which is retained in the filtered liquor, may be thrown down by phosphate of soda in the form of ammonio-magnesian phosphate, or the solution may be evaporated to dryness, and the residue heated red-hot so as to leave magnesia. Evaporate the hydrochloric solution of the two earths to dryness, and expel the excess of acid from the residue, by heating in a platinum crucible: powdered chlorate of potassa is then added so long as the evolution of chlorine is perceived. On treating the residue with water, chloride of calcium and chloride of potassium are dissolved, and pure magnesia remains, which is separated upon a filter, washed, ignited, and weighed; the lime in the filtrate may be precipitated by oxalate of ammonia.

Separation of magnesia from the fixed alkalies.—Add subphosphate of ammonia to the solution, to throw down the magnesia as ammonia-phosphate, and filter; add acetate of lead to the filtrate, as long as it occasions any precipitate; filter again and supersaturate the clear liquor with sulphide of hydrogen; separate the sulphide of lead, and evaporate the solution to dryness. The residue, consisting of acetates, may be converted by hydrochloric acid into chlorides of potassium and sodium, which may be dissolved in water, and chloride of platinum will then throw down the potassium, which may be estimated from the weight of the potassio-chloride.

Quantitative Analysis.—This alkaline earth is almost invariably precipitated from an ammoniacal solution by phosphate of soda; it is collected and washed, and ignited so as to be weighed in the state of pyrophosphate. Every one hundred parts of ammonio-magnesian phosphate, dried at 60°, indicate 16·26 of magnesia:

every one hundred parts of its residue, after ignition, indicate 35·7 parts of magnesia.—*Brande.*

LIEBIG proposed another method to separate magnesia from potassa and soda. The bases are combined with sulphuric acid, the solution is rendered neutral, and is precipitated by a solution of sulphide of barium, which separates all the potassa and all the soda from the magnesia. The alkalies remain in the liquor in the state of sulphide of potassium, or of sodium, together with the excess of sulphide of barium employed. This liquor is decomposed by sulphuric acid, and the sulphate of baryta produced is collected on a filter; by evaporating the alkali, the sulphate of alkali is obtained. This alkaline product is then to be weighed, and from this weight the quantity of the alkali may be calculated. The best method of extracting the magnesia from the precipitate produced by the sulphide of barium—a precipitate which consists of magnesia mixed with sulphate of baryta—is to use an acid, and sulphuric acid in preference—to filter, in order to separate the sulphate of baryta produced, and the magnesia may be determined afterwards as a sulphate of magnesia.

The sulphide of barium employed for this method of analysis, must be crystallized and washed with cold water; such as it is obtained from the boiling of the product of the calcination of a mixture of sulphate of baryta and of charcoal.

Hydrate of baryta may be substituted for sulphide of barium with the same result.

The fixed alkalies may be more easily separated from magnesia when these bases are combined with nitric acid. The nitrates are to be calcined, which may be done in a platinum crucible, by adding a little dry carbonate of ammonia to the mass, after exposure to the first impression of the heat, and then moderately urging the fire. When the calcining is finished, the residuum is treated with water, which dissolves the alkalies in the state of carbonates, and leaves the magnesia behind.

When the fixed alkalies and magnesia are contained in a solution in the state of metallic chlorides, the method formerly in use for separating them consisted in evaporating the liquor to dryness, and igniting the dry residuum; the water of crystallization of the chloride of magnesium converted the latter into magnesia, with disengagement of hydrochloric acid; after which the chloride of the alkalisable metal was separated from the magnesia by washing with water.

This method may often be employed with advantage in qualitative analysis, but in quantitative the results obtained by it *are quite inaccurate*; for even after a protracted ignition there remains a great quantity of undecomposed chloride of magnesium, which dissolves in the water with the alkaline chloride. If strong alcohol is employed instead of water for washing the strongly ignited mass, it does not give a better result, for alcohol dissolves the undecomposed chloride of magnesium, just as water does, and leaves the magnesia thus produced undissolved.

Yet if, after having put the mixture of chloride of magnesium and of the alkalisable metal in a small platinum crucible, it is exposed to a red heat for a long time over a gas lamp, placing at the end a small piece of carbonate of ammonia upon the mass, and then igniting strongly, nearly the whole of the chloride of magnesium may be converted into magnesia; but the calcination with the ammoniacal salt *must be repeated several times*, and the salt must be moistened with a few drops of water before calcining. The operation is known to be at an end when the weight of the saline mass remains constant after ignition. It is then treated by water, which dissolves the alkaline chloride, and along with it a trace of magnesia. The magnesia which remains insoluble is ignited and weighed. It is completely soluble in nitric acid, and when tested by nitrate of silver hardly shows a trace of chlorine. During the ignition of the mass it is advisable to put the cover on the crucible, in order to keep in the vapor of carbonate of ammonia as long as possible, and to prevent, at the same time, the access of air.

When the operation is performed on a few grammes of a mixture of chloride of magnesium, and of the chloride of an alkalisable metal, the treatment with carbonate of ammonia and water must be repeated at least eight times. The unavoidable loss of chlorine, which takes place when this method is resorted to, does not amount to one per cent. Of course, the chlorides which the operator purposes to separate *must contain no trace of sulphuric acid.*

In order to avoid the tedious operations which are necessary for an actual separation of magnesia, potassa, and soda, particularly when they do not exist together in the state of pure chlorides, Dr. LIST endeavored to determine them conjointly by an indirect method. The following is the process he found practically applicable in the most complicated cases, such as is presented by the analysis of a silicate decomposed by hydrofluoric acid:—

The filtrate obtained after precipitation of all other bases, is evaporated to dryness in a water-bath, and the residue of sulphates and chloride of ammonium cautiously ignited in a platinum crucible to expel the ammoniacal salt. The perfect safety of this operation from all loss may be insured by employing a crucible lid with an interior convex surface. As it is an indispensable condition for the success of the subsequent result that sulphuric should be the only acid present, the ignited saline mass is moistened with a little sulphuric acid, and again evaporated to dryness. To change the acid salts into neutral, a piece of carbonate of ammonia is then placed in the crucible, and this again heated until the bottom becomes feebly red. This operation is repeated until the weight remains constant. This chemist ascertained that the pure sulphate of magnesia loses no sulphuric acid. The contents of the crucible are now dissolved in water, and the sulphuric acid in the solution determined by chloride of barium; when the excess of baryta has been removed by sulphuric acid, the magnesia is precipitated by ammonia and phosphate of soda, and determined in the usual manner.

Dr. LIST proved the applicability of this method by operating upon a known mixture of sulphates of potassa, soda, and magnesia. After having convinced himself of the purity of the individual salts, by a determination of their sulphuric acid, he mixed the three, and, analysing the mixture, found the required quantities within 0·001 per cent.

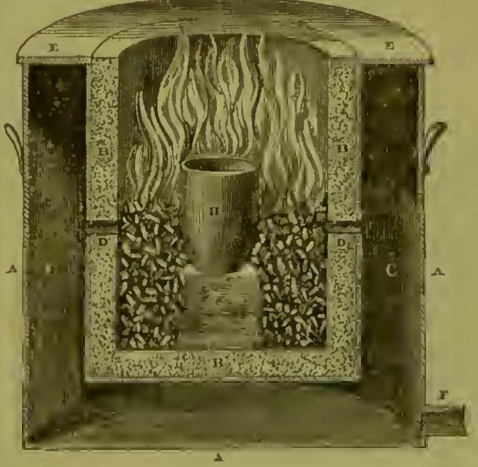
The sources of this minute error are certainly of much less importance than those which are found to exist in the process by direct separation, especially as the determination of sulphuric acid and magnesia is one of those operations which can be effected with the greatest accuracy.

MANGANESE.—*Manganèse*, French; *Mangan*, German; *Manganum*, Latin.—The black mineral known in commerce by the name of manganese—*braunstein*, German—has long been employed to counteract the green tint of glass. It was formerly called *magnesia nigra*, from its resemblance to the magnetic oxide of iron, or loadstone. A mine of this mineral was discovered in England by BOYLE. Some experiments were made upon it by GLAUBER in 1656, and by WAIZ in 1705; but chemists do not appear to have directed particular attention to it until a later period. Mineralogists agreed in classing it among the ferruginous ores until POTT, in 1740, showed that it often contains mere traces of iron; after which, on the supposition that it consisted chiefly of a peculiar earth, a separate place was assigned to it in treatises on mineralogy. This hypothesis was, in the year 1774, distinctly proved to be correct, by the elaborate researches of SCHEELE and BERGMAN. GAHN subsequently showed that this earthy base contained a metal, not hitherto isolated, upon which he bestowed the appellation of *magnesium*. As, however, this term was afterwards employed to distinguish the metallic base of magnesia, it was superseded by the designation now in use. The metal manganese, owing to its powerful attraction for oxygen, does not occur in a free state in the earth's crust; but its mineral oxides are abundant, and are extensively employed in the arts, chiefly in the manufacture of glass and pottery, and in the preparation of chlorine for the production of bleaching-powder.

PREPARATION.—From the difficulty of its isolation, metallic manganese has not been rendered available for any useful purpose. The processes for its reduction are generally conducted on a small scale, in the laboratory. Like iron and cobalt, it is very difficult to be obtained in a state of absolute purity. It is necessary, in the first place, to procure a pure oxide of manganese, which may be effected by any of the following processes:—The common black oxide of manganese of commerce is digested for some time with dilute hydrochloric acid, washed, in order to free it from carbonate of lime, and then heated with strong hydrochloric acid. During the solution of the mineral, chlorine gas is abundantly disengaged, and, when the action is complete, the solution contains chloride of manganese and sesquichloride of iron. The liquid, after filtration, is evaporated to dryness in a porcelain basin, and the dry residue is strongly heated, with constant stirring, until it assumes an ash-grey hue, and no longer evolves acid fumes. By this treatment the chloride of iron is in part volatilized, and in part converted into sesquioxide of iron and hydrochloric acid. The residue is now digested with water, the solution filtered, and carbonate of soda, in slight excess, added to the liquid. The precipitated carbonate, after washing and drying, is ignited, when it furnishes a pure oxide; or the solution in hydrochloric acid is diluted with water, and treated with repeated quantities of carbonate of soda, with continued digestion and stirring, until the liquid, rendered clear by subsidence or filtration, gives a pure white precipitate with a further quantity of carbonate of soda, showing that all the oxide of iron has been precipitated. This having been attained, the whole solution is freed by filtration from the precipitate, and the clear liquid precipitated by carbonate of soda in excess.

FARADAY recommends the following process for the preparation of pure protochloride of manganese:—Finely-powdered and strongly-calcined black oxide, previously cleansed from carbonate of lime, is ignited with half its weight of chloride of ammonium, beginning with a moderate heat, and gradually raising the temperature to low redness. The chloride of manganese formed is dissolved out and the solution filtered. The pure oxide of manganese, prepared by the process already indicated, is moistened with oil and heated to redness several times, then made into a thick paste with oil, introduced into a charcoal-lined crucible, covered with charcoal powder, and a lid luted on the mouth of the crucible, which is afterwards exposed, for two or three hours, to the strongest heat of a smith's forge or a powerful blast furnace. SEFSTROM's apparatus, represented in Fig. 355 is commonly employed for the reduction. In a cylindrical iron case, A, is placed a second cylinder, B, lined with fire-brick. The crucible is arranged as represented in the drawing, and surrounded with glowing charcoal or coke. The blast is admitted at F into the space which intervenes between the two cylinders, from which, after becoming considerably heated, it is forced into the fire-chamber through a series of openings, D D. The metal collects in the form of a button at the bottom of the crucible.

Fig. 355.



PROPERTIES.—Metallic manganese, as thus obtained, presents a greyish-white color without much lustre, and a fine granular texture. It is rather soft and brittle, and is readily split or broken. Its specific gravity is stated by JOHN to be 8·013. Its equivalent is 27·6. When pure it is not attracted by the magnet. It is exceedingly difficult of fusion, requiring for liquefaction the most intense heat of a wind furnace. The manganese prepared by the process described is always contaminated with carbon and silicium, and resembles, therefore, common pig or cast iron. On subjecting the metal to fusion with borax, the carbon is separated, and the regulus becomes more fusible; but it is probable that the product, in this case, contains boron or sodium. Manganese readily tarnishes by exposure to the air—hence, like potassium, it must be kept under naphtha. When heated to redness in open vessels, it absorbs oxygen with rapidity. It decomposes water slowly at common temperatures, with disengagement of hydrogen gas; but at a red heat oxidation is very rapid. It also dissolves readily in dilute acids, with escape of hydrogen. By fusion at a high temperature, manganese may be alloyed with various other metals. A compound of about four equivalents of manganese and one equivalent of iron, was produced in considerable quantity by BUTTRAY, in a furnace employed for fusing cast-steel. This alloy became only slightly tarnished when freely exposed to the air, and did not affect the magnetic needle. When manganese is combined by fusion with six or seven *per cent.* of silicium, a regulus results which possesses the appearance of the ordinary metal, but differs much from it in its chemical characteristics; it does not oxidise, even at a red heat, and withstands the action of nitro-hydrochloric acid—*Sefström.*

BERZELIUS expressed the opinion, that the presence of the small proportion of silicium is not sufficient to account for this total change of properties, and that there must exist in the compound or alloy, an allotropic modification of the metal, the alteration being effected or induced by the presence of the silicium at a temperature at which it would not occur with manganese alone.

C. BRUNNER has recently prepared metallic manganese, by acting upon the fluoride with half its weight of sodium, the process being similar to that employed for the reduction of aluminium. Manganese thus obtained possesses properties essentially different from those usually attributed to this metal. Its color is like that of some cast-iron; it is brittle and very hard, not yielding to a steel file, but, on the contrary, scratching the best-tempered steel. It is capable of the most perfect polish. It is not altered even in moist air at the ordinary temperature. When heated, it acquires nearly the same colors as steel, passing afterwards to brown, by covering itself with a layer of oxide. The specific gravity of different specimens varied from 7·138 to 7·206. It is not attracted by the magnet, even when in powder, and has no influence on the magnetic needle. Acids attack it violently, even in the cold.

OXIDES.—Manganese forms at least five distinct compounds with oxygen, besides several compound oxides. The composition of these oxides is exhibited in the following table:—

Protoxide, or manganous oxide,	$Mn\ O$.
Sesquioxide, or manganic oxide,	$Mn_2\ O_3$.
Binoxide, or peroxide—black oxide,	$Mn\ O_2$.
Manganoso-manganic oxide—red oxide,	$Mn_3\ O_4$, or $Mn\ O, Mn_2\ O_3$.
Varvicite,	$Mn_4\ O_7$, or $Mn_2\ O_3, 2\ Mn\ O_2$.
Manganic acid,	$Mn\ O_3$.
Permanganic acid,	$Mn_2\ O_7$.

Of these the first only possesses marked basic properties; the sesquioxide is a very feeble base; and the two compounds at the bottom of the list are, as their names indicate, acids. The protoxide is readily obtained by heating the oxalate in a covered crucible or in a glass tube closed at one end. When a caustic alkali is added to a solution of chloride or sulphate of manganese, the hydrated oxide falls as a flocculent white precipitate, which rapidly acquires a dark tint on exposure to the air. Binoxide of manganese may be prepared by passing chlorine gas through a solution of the acetate. Sesquioxide of manganese is produced when the binoxide is kept for a considerable time at a moderate red heat: it also occurs in nature as *braunite* and *manganite.* The red or manganoso-manganic oxide is always produced when any of the higher oxides is exposed to a white heat, either in closed or open vessels, or when hydrated protoxide is exposed to the air. It is the most permanent of all the oxides of manganese; it is not affected by exposure to any temperature, while all the other oxides readily pass into it, under the influence of heat. When finely powdered it is brownish-red while cold, and nearly black while warm. When fused with borax or glass, it communicates to these bodies a beautiful violet or amethyst tint, a character by which manganese may readily be detected before the blowpipe. Many colored minerals—for example, the amethyst—owe their tint to the presence of this oxide. Manganate of potassa is readily produced by fusing binoxide with carbonate or hydrate of potassa, with or without the addition of chlorate. The compound has a fine green color. Upon the ready formation and great coloring power of manganic acid, E. DAVY has founded an elegant method for the detection of manganese. The substance is heated on silver foil, with a drop of a strong solution of caustic potassa, and the dry residue is gently ignited, when it will exhibit, if manganese be present in appreciable quantity, a very distinct green color. When compounds of manganese are heated before the blowpipe with carbonate of soda, on a loop of platinum wire, a green bead is obtained, manganate of soda being formed. Manganate of potassa has received the name of *chameleon mineral*, from the circumstance that the dark-green solution obtained by digesting it in a small quantity of cold water, assumes various shades of color on being diluted, the ultimate result being a liquid, having a fine carmine-red tint. The change of tint, which is induced more readily by the addition of an acid, is owing to the resolution of the manganic into permanganic acid, which remains in solution, and binoxide of manganese, which falls as a precipitate.

$$3\ Mn\ O_3 = Mn_2\ O_7 + Mn\ O_2.$$

CRUM'S test for manganese depends upon the formation of permanganic acid. The compound under examination is dissolved in a little nitric acid, and binoxide of lead added, when, the fine red tint of permanganic acid will be communicated to the liquid. Solution of permanganate of potassa is much employed in the German and French laboratories as an oxidising agent: in this country the bichromate is more generally used. The solution is best prepared by the method recommended by GREGORY. Four parts of finely-pulverized binoxide of manganese, and three and a half parts of chlorate of potassa, are intimately mixed together, and added to five parts of hydrate of potassa dissolved in a small quantity of water. The mixture is evaporated, and the residue completely dried, pulverized, and exposed to a low red heat, in a platinum crucible. The agglutinated mass is again powdered and added to a considerable quantity of boiling water, and the solution allowed to settle. When clear it is decanted, and is ready for use. It is quite permanent when preserved in well-stoppered bottles.

All the higher oxides of manganese are reduced to the condition of protocompounds by the action of warm sulphuric or hydrochloric acid, with the elimination of oxygen or chlorine, as the case may be. The following equations represent the action of hydrochloric acid upon the binoxide, the sesquioxide, and the red oxide of manganese:—

$$Mn\ O_2 + 2\ H\ Cl = Mn\ Cl + 2\ HO + Cl.$$
$$Mn_2\ O_3 + 3\ H\ Cl = 2\ Mn\ Cl + 3\ HO + Cl.$$
$$Mn_3\ O_4 + 4\ H\ Cl = 3\ Mn\ Cl + 4\ HO + Cl.$$

Protoxide of manganese is a powerful base of the magnesian class. Its salts are sometimes quite colorless; but they frequently possess a pink shade, probably from the presence of traces of permanganic acid, or oxide of cobalt. The soluble salts are nearly neutral, and when dissolved exhibit the following reactions:—

Caustic Potassa,............	A white precipitate of hydrated protoxide, which becomes brown by the absorption of oxygen.
Ammonia,..................	Do.
Alkaline carbonates and bicarbonates,................	White precipitate.
Ferrocyanide of potassium,...	Do.
Sulphide of hydrogen,.......	No effect in acid solutions.
Sulphide of ammonium,......	A flesh-colored precipitate.

For the detection of minute quantities of manganese, especially when mixed with other metals, CRUM'S test, already detailed, is probably the most delicate.

ORES.—The compounds of manganese which occur native are numerous, but as those only are of importance in the arts, which consist solely or chiefly of one of the higher oxides, the minerals which come under consideration in this place are comparatively few in number.

Pyrolusite is the name applied to the native binoxide in its anhydrous and crystallized state. It is chiefly this variety that is employed by the glass-makers, while *wad* and other less pure ores are consumed in the elimination of chlorine from hydrochloric acid or chloride of sodium. The crystalline form of pyrolusite is the rhombic prism, and it generally occurs in the form of minute crystals grouped together, and radiating from a common centre. It has the same form as *manganite*, which consists of hydrated sesquioxide, and appears to be formed from that mineral by absorption of oxygen and loss of water, some masses of crystals having been observed to consist of pyrolusite externally and manganite internally. Pyrolusite has an iron-black or dark steel-grey color, and a metallic lustre. It is not very hard; its specific gravity is 4·7 to 4·97. It frequently contains *manganite*, *psilomelane*, sesquioxide of iron, alumina, silica, baryta, carbonate and sulphate of lime, and occasionally, according to PHILLIPS, traces of chloride of calcium. The following analyses of specimens of pyrolusite are by TURNER:—

	Elgersburg.	Ihlefeld.
Binoxide of manganese,..........	97·84	97·22
Baryta,..........................	·53	·66
Silica,..........................	·51	.55
Water,..........................	1·12	1·57
Chloride of calcium,.............	—	traces
	100·00	100·00

This valuable ore is extensively worked in Ilmenau, Elgersburg, and various other districts in Thuringia; and the mines at Vorderschrensdorf, in Moravia, yield annually many hundred tons. It has also been found in several localities in America and elsewhere.

Name of Ore.	Locality.	Composition.							Analyst.	= MnO_2
		Binoxide of manganese.	Sesquioxide of manganese.	Sesquioxide of iron.	Baryta.	Lime.	Clay.	Water.		
Wad,.............	Grorio, Mayenne,........	64·2	11·0	6·0	—	—	3·0	15·8	Berthier.	70·2
"	Viodessos,..............	54 6	26·0	7·0	—	—	—	12·4	"	68·9
"	Granbundten,...........	22·6	31·0	3·6	—	—	Quartz. 33·6	8·8	"	39·6
"	Upton Pyne, Devon,......	61·7	23·2	—	1·4	—	—	10·7	Turner.	76·1
"	Ilmenau,................	51·6	27·0	1·0	8·1	—	Silica. 2·5	9·8	Scheffler.	66·4
"	Rubeland,...............	66·0	15·0	1·0	·3	And KO. 6·9	·5	10·3	Rammelsberg.	74·2
Ochrey Wad,......	"	73·3	23·6	—	trace	—	—	3·1	Turner.	86·3
Varvicite,.........	Warwickshire,...........	50·	45·	—	—	—	—	5·	"	74·7
Psilomelane,.......	Schneeberg,.............	54·5	22·7	—	16·4	—	·2	6·2	"	66·0
"	Baireuth,...............	74·3	17·0	—	—	Potash. 4·5	—	4·2	Fuchs.	83·6
Braunite,..........	Elgersburg,.............	—	96·8	—	2·3	—	trace	·9	Turner.	53-2
Manganite,........	Ihlefield,...............	—	89·9	—	—	—	—	10·1	"	49·4
Hausmannite,......	"	Protoxide. 30·7	68·3	- -	·1	—	.4	·5	"	37·5

Wad is the native hydrated binoxide. It is this ore that is commonly employed in the preparation of chlorine. It is tolerably abundant, and is found in England, Ireland, Sweden, Germany, and America; it appears generally in the form of brownish-black masses, or loosely agglomerated brown scales. Some varieties are hard and compact, and difficult to pulverise; others are compatively soft and ochrey. Wad consists essentially of hydrated binoxide of manganese, $Mn\ O_2$, HO, but it is always more or less mixed up with manganic or manganoso-manganic oxide, and generally with variable quantities of sesquioxide of iron, clay, quartz, baryta, carbonate of lime, *et cetera*. Some specimens contain much oxide of cobalt, and a few contain oxide of copper. Analyses of specimens of wad from various localities, and of other ores of manganese capable of being applied to economic purposes, are exhibited in the preceding table. The last column of the table shows the amount of pure binoxide corresponding with the quantity of chlorine yielded by one hundred parts of the ore.

Psilomelane is one of the most generally diffused ores of manganese. It is compact and fibrous; specific gravity 4 to 4·328; rather hard. It has a dark steel-grey color, and submetallic lustre; it generally occurs in botryoidal masses.

Braunite is met with in octohedral crystals, and also massive; it is commonly nearly pure sesquioxide of manganese. *Manganite*, or grey manganese ore, is the hydrated sesquioxide, $Mn_2\ O_3$, HO, and is generally very pure, and, therefore, well adapted for the manufacture of glass. It occurs in rhomboidal prisms, and also in columnar and granular masses. It is moderately hard; specific gravity 4·3 to 4·4; color between iron-black and steel-grey, with a submetallic lustre. It is found at Ihlefeld in the Hartz, in Aberdeenshire, Bohemia, Saxony, and other localities.

USES.—The most important applications of manganese ore in the arts, are the production of chlorine and the decoloring of glass. Although, in the manufacture of glass, the purest materials are employed, yet traces of iron compounds are invariably present in one or more of the materials, giving to the product a very faint but distinct green, olive, or yellow tint, according to the state of oxidation of the metal. The cautious addition of black oxide of manganese destroys or conceals the objectionable tint. Its action was formerly supposed to be merely the oxidation of the green protoxide of iron to the faint yellow sesquioxide; but LIEBIG has suggested that the effect is not chemical but optical, and that the amethyst color communicated by the red oxide of manganese counteracts the yellow or greenish-yellow tint of the oxide of iron. This is probably the correct explanation of the action, since other oxidising agents, red oxide of lead for example, do not produce the desired effect. Chemists employ the binoxide of manganese for the preparation of oxygen and chlorine gases, and it is employed, in conjunction with dilute sulphuric acid, as an oxidising agent in organic chemistry.

Binoxide of manganese has been employed for increasing the siccative quality of linseed oil; and the artificial binoxide, mixed with the same oil, has been recommended as a black paint, which may be used with advantage for the manufacture of printers' ink.

Of the numerous combinations of manganese with the halogens, and of the oxides with acids, the acetate, protochloride, and the sulphate of the protoxide are the only compounds which are manufactured on the large scale or applied to economic purposes, and are, consequently, sufficiently important to claim consideration in a work on technology.

Acetate of Manganese.—A full description of this salt is given in Vol. I., page 46.

Chloride of Manganese.—A solution of this compound in a state of purity is most readily obtained by the method recommended by FARADAY, already detailed, or by digesting a solution of purified black oxide of manganese in hot and strong hydrochloric acid, with carbonate of maganese, until all the sesquioxide of iron is displaced and thrown down. When the solution is highly concentrated by evaporation, it yields crystals of the hydrated salt, Mn Cl, 4 HO. These crystals are highly deliquescent, and they dissolve in two-thirds of their weight of water at 60°, and in a much smaller quantity at a higher temperature. The salt may be rendered anhydrous by the application of the heat of a spirit flame, while inclosed in a glass tube through which a current of dry hydrochloric acid gas is made to pass. It is a rose-colored crystalline mass.

Chloride of manganese is a refuse or waste product in chemical factories where chlorine is prepared from manganese and hydrochloric acid. It has been employed in the purification of coal gas. It may be used in dyeing for the production of *manganese-brown*, but the sulphate is generally employed for this purpose. A crude solution of chloride of manganese, neutral and free from iron, may be prepared by digesting the refuse menstruum already referred to with powdered chalk, which decomposes the sesquichloride of iron, but does not affect the manganese salt.

Sulphate of manganese is obtained in transparent, slightly rose-colored crystals, by dissolving the pure carbonate in dilute sulphuric acid, and concentrating by spontaneous evaporation. The crystals have the form of sulphate of copper, and a similar composition, $Mn\ O,\ SO_3 + 5\ HO$; but by evaporation and crystallization at various temperatures, crystals with greater and less proportions of water may be obtained. The crystals are remarkably soluble in water.

This salt is prepared on a considerable scale for the use of the dyer and calico-printer. The mode of preparation generally adopted is as follows:—Black oxide of manganese is ignited with a small quantity of charcoal powder, in order to reduce it to the state of protoxide. This product being now treated with moderately dilute sulphuric acid, a crude sulphate is obtained containing a considerable proportion of sulphate of iron, to get rid of which the solution is boiled down to dryness, and the residue ignited or roasted. The mass is digested with water, when the manganese salt dissolves, while the iron remains insoluble as a basic sesquisulphate. The salt is obtained from the solution by evaporation. Another mode of preparation is, to ignite a mixture of black oxide of manganese and sulphate of iron, then to digest in water, and evaporate the solution. *Manganese brown*, or *bronze*, is produced by immersing the fabric in a solution of sulphate of manganese, and then in one of dilute caustic alkali to precipitate the protoxide, which is raised to a higher state of oxidation either by simple exposure to the air, or, more rapidly, by transmitting it through a solution of bleaching powder.

PROCESSES FOR THE RECOVERY OF MANGANESE.—It has been customary for manufacturers who eliminate chlorine on the large scale, to throw away the chloride of manganese that results. To prevent this enormous loss of valuable material, various methods have been proposed and patented for recovering the manganese, or reconverting the chloride into the binoxide or sesquioxide. It is well known that the protoxide of manganese is readily converted by the oxygen of the air into the sesquioxide by gentle ustulation; and it was mentioned long ago by FORCHHAMMER, that carbonate of manganese, when heated in an open vessel to 500°, is converted for the most part into binoxide, an observation which does not seem, until very lately, to have attracted that degree of attention which its importance merits. The two most recent patent processes for the recovery of manganese, are those of BALMAIN and DUNLOP.

The invention of W. H. BALMAIN, whose patent is dated 31st March, 1855, is a method for attaining an economical recovery of the oxide of manganese by carrying on the process in conjunction with the manufacture of chloride of ammonium from the ammoniacal water formed in making coal gas. The mode of proceeding is as follows:—Into a convenient tank or pan, a quantity of the ammoniacal gas water is run, and to it is added the solution of manganese produced in the manufacture of chlorine, until a further addition of the solution causes no precipitation or thickening, or until the supernatant clear liquor does not effervesce with acid. The mixture having been allowed to stand for some time, the clear liquor is drawn off and evaporated for the purpose of crystallizing out the chloride of ammonium which it holds in solution. Water is then run upon the sediment, which is agitated, and is then allowed to subside. The supernatant clear liquor is then drawn off and treated in the same manner as the first liquor, in order to extract from it the remaining chloride of ammonium. The sediment is now removed to a bed of sand or cinders, and allowed to lose as much water as will mechanically run off by drainage. It is then placed upon a hearth or ordinary furnace-bed, and heated to redness, either by means of an open fire or by flues above and below, until it ceases to burn like tinder, and has assumed a black color; by which time it will have been converted into an oxide of manganese, fit for use, in the manufacture of chlorine, or for any other purpose to which it might have been applied in its original form.

When the manganese is to be used for producing chlorine, it is advisable to mix lime with the sediment before drainage, or as soon as it dries upon the hearth, and thus resolve it more or less into manganate of lime, which increases its power of eliminating chlorine.

When the gas water to be operated upon is in a town at a distance from the spot where the solution of manganese is produced, or when the recovered manganese is to be used in the manufacture of glass, the liquid chloride of manganese is boiled down, and heated in a furnace to such a temperature as will render oxide of iron insoluble; in which state it is carried to the neighborhood where the gas water is produced, and being redissolved in water, is mixed and treated as described in the first instance.

The oxide of manganese having been used a second time, may be again recovered a third and a fourth time; and if no lime or alkali-waste has been used in neutralizing the excess of acid, it may be recovered an indefinite number of times.

The patent granted to CHARLES TENNANT DUNLOP, and dated 31st May, 1855, relates to the employment of the residuum obtained in the manufacture of chlorine, which residuum ordinarily consists of chloride of manganese, in the preparation of an artificial oxide of manganese, that is well suited for the manufacture or production of chlorine. The special process preferred by the patentee in carrying out his invention, is the transformation of the chloride of manganese into a carbonate of that metal by the agency of any of the means already well known to chemists, and then subjecting the carbonate, thus prepared, to the action of heat in contact with atmospheric air. Whatever impurity the chloride of manganese may contain—as chloride of iron for instance—is first separated either by calcination, or by the agency of a suitable precipitant. Practical working has decided that the carbonate of manganese, thus treated, yields an oxide of manganese of a richness equivalent to about eighty per cent. of pure sesquioxide.

The carbonate of manganese may be obtained by precipitation from the chloride, by the agency of carbonate of ammonia. The chloride of ammonium resulting from this treatment, may either be sold or employed as such, or it may be converted into a carbonate in the usual way, and then again employed for the precipitation of fresh chloride of manganese. Hydrate of lime is also employed in the production of carbonate of manganese from these residual matters; the hydrated oxide of manganese being subsequently transformed into carbonate by the transmission through it of carbonic acid.

By another process, carbonate of manganese is obtained by passing carbonic acid through the solution of chloride of manganese, which has been previously mixed with a quantity of carbonate of lime. The carbonate of lime, under the influence of the carbonic acid, decomposes the chloride of manganese into carbonate, from which the oxide of manganese can be obtained, as well as chloride of calcium, which remains in solution. The production of oxide of manganese, suitable for the preparation of chlorine, has often been attempted by following the process of precipitating the manganese as an oxide, and then bringing it to a higher state of oxidation by heating it in contact with atmospheric air, as well as by other means. But the essential feature of this invention is, the production of oxide of manganese from the residuum of the chlorine manufacture, by first manufacturing or producing the carbonate of manganese, and then heating this carbonate in contact with atmospheric air. Dunlop's process has been most extensively and successfully carried out by the Messrs. Tennant of the St. Rollox Chemical Works, Glasgow. The carbonate is obtained in this establishment by heating in an iron boiler, under pressure, chalk and the refuse chloride of manganese, from which any iron which it may contain has been previously separated by the action of chalk in the cold. The carbonate of manganese thus procured is freed from the chloride of calcium in vats, collected, and then exsiccated in a chamber on a series of iron trays, in such a gradual manner as to expel the carbonic acid, and by elevating the temperature in a current of air, to obtain the black oxide.

Quantitative Estimation.—Manganese is weighed almost invariably as the red oxide $Mn_3\,O_4$, 114·8 parts of which are equivalent to 82·8 of metallic manganese, 106·8 of protoxide, and 130·8 of binoxide. When no other base is present, or only the alkalies, the moderately dilute solution is heated to boiling, and the manganese is thrown down as carbonate by the addition of carbonate of soda in excess. The precipitate is collected on a filter, washed with boiling water, dried and ignited over a powerful lamp or in a furnace, until the weight ceases to vary. The residue in the crucible is pure red oxide. If the liquid contains ammoniacal salts, it must be boiled with carbonate of soda in excess until the odor of the volatile alkali is no longer perceptible.

When any of the metals precipitable by sulphide of hydrogen are contained in the liquid, it must be rendered acid by the addition of hydrochloric acid, and treated with this agent, in order to remove them. Sesquioxide of iron is most readily separated by the addition of succinate of ammonia to the nearly neutral liquid. Manganese may be separated from the alkalies, earths, and the oxides of iron, nickel, and zinc, by the ingenious method of Schiel. The acid menstruum is nearly neutralized with carbonate of soda, acetate of soda added, and chlorine gas passed through the liquid to saturation. The manganese is completely deposited as hydrated binoxide, which may be converted into red oxide by ignition; the other bases remain in solution. The absolute separation of manganese and cobalt is attended with considerable difficulty; but the following simple method gives results which are sufficiently accurate for all technical purposes:—The two metals are precipitated by sulphide of ammonium and excess of acetic acid then added, when the sulphide of manganese dissolves, and the sulphide of cobalt remains intact.

The separation of manganese from nickel is given under the latter metal. Having obtained the sulphide of manganese by the process mixed with sulphide of zinc, it will be well to give here the mode of obtaining the manganese *per se*. Dissolve the sulphide in hydrochloric acid, then nearly neutralize with carbonate of soda, add acetate of soda, and next conduct chlorine gas into the mixture. The manganese salt is hereby decomposed, and the whole of the manganese separates as binoxide. The zinc remains in solution.

For the valuation and testing of manganese ores, the reader is referred to the article Bleaching Powder, Vol. I., page 329.

Physiological Effects.—The effects of manganese upon the system are imperfectly known. Kapp regard it as a permanent stimulant, and says it promotes the appetite and digestion. Vogt places it among the tonics, and considers it to be intermediate between iron and lead; but his views are altogether theoretical, as he does not seem to have prescribed it. Dr. Couper has described several cases of disease which took place among the men engaged in grinding it at the chemical works of Messrs. Tennant and Company, in Glasgow; from these, it appears that, when slowly introduced into the system, it produces paralysis of the motor nerves. The disease commences with symptoms of the paraplegia. It differs from the paralysis of lead in not causing *colica pectorum*, or constipation; and from mercury, in first affecting the lower extremities, and in not exciting tumors of the afflicted part.

Manganese is rarely used in medicine; it appears to have been employed in the last century in the treatment of inflammatory fevers. Grille long since observed that the workmen in the manganese mines at Maçon were not subject to the itch; and that others who became affected with this disease, were cured by working in the mines. This led him, as well as Morelot and others, to employ it in cutaneous maladies. Kapp administered it, as well as the salts of manganese, both internally and externally in various forms of syphilis; he used it with benefit in herpes, scabies, and the scorbutic diathesis. Brera gave it in chlorosis, scorbutus, hypochondriasis, hysteria, *et cetera.* Otto administered it in cachectic complaints, with favourable results. Odier employed it in cardialgia. It has been applied as an absorbent in the treatment of old ulcers, as a depilatory, and as a remedy for skin diseases, especially itch and porrigo. Kugler gave it with benefit in scrofula.

Manganic Acid.—Hunefeld gave to a rabbit nearly two drachms of manganic acid in three days, in doses of ten or fifteen grains. The only obvious effect was increased secretion of urine. The animal being killed, the peritoneum and external coat of the colon were found of a greenish color—protoxide of manganese is of a pale grass-green color—the muscles were readily lacerated and livid, the liver was inflamed, the bile increased.—*Pereira.*

Statistics.—For all purposes, about twenty-five thousand tons of manganese are used annually; and of this quantity, from seventeen to eighteen thousand are employed for the manufacture of bleaching powder. The largest makers of the latter article are the Tennants of Glasgow, and Muspratts of Liverpool, and Flint, North Wales.

MANURE.—*Engrais*, French; *Dünger*, German. The term, *manure*, is applied to all those substances which render soils more fertile. Manures produce their effects by contributing directly to the nutriment of plants, by improving the texture of soils, or by acting as chemical agents on the inert matters of the soil, by which they are transformed into a state fit for the use of plants.

Manures consist of vegetal and animal substances, and of their products of decomposition, or of earthy, saline, and other bodies derived from minerals; consequently, they have generally been classed into vegetal and animal manures, mineral and mixed manures.

The history of manures cannot date so far back as the origin of agriculture, which was coeval with the foundation of society itself. In the earlier periods of the world, when the face of the ground was but thinly inhabited, and a virgin soil exhibited abundant fertility, the wants of man were readily supplied. With ample choice of ground at his command, he had only to remove to another spot, when land already under cultivation for some time no longer yielded the same increase. The fact of diminished productiveness, by prolonged cultivation, was no doubt early observed; but the reason of this did not probably give rise to much speculation, so long as the remedy was at hand in the fresh soil around. But as population increased, and the habits of men became less nomadic, the necessity of restoring to the exhausted soil its fertility, would become a question of serious consideration. The mode of doing this in the simplest way, would suggest itself by the observation of what passed around them. The refuse materials ejected from their habitations, the ordure of man and animals, the decaying carcasses of the latter, allowed to accumulate and rot on the surface of the ground, gave rise to a luxuriant vegetation on these spots, far surpassing that of the adjacent soil. The repeated observation of such facts cannot fail to have arrested attention, and to have led, on reflection, to connect cause and effect. It was thus early seen, that organic structures in a state of eremacausis, the filth from crowded habitations, and other matters which are offensive to the organs, when allowed to decay on exposure, were intended by nature to be buried under ground, and thus to effect at once the removal of pollution from the air that was breathed, and to restore the lost fertility of the soil. Hence the earliest form of manure, and that which has remained unchanged through succeeding ages, and at the present day still forms the standard of comparison for other manures, was a mixture of the recrement and urine of animals with other decaying animal and vegetal matter. In the writings of the Greeks and Romans are found many notices of the attention they paid to agriculture and manures.

Columella, who flourished during the early part of the first century of the christian era, wrote a great work, divided into twelve books, on agriculture. In the second of these he speaks of the breaking up and preparation of the ground, and gives an account of the different kinds of grain, pulse, and artificial grasses, with the tillage appropriate for each. He gives directions for carefully collecting the excrement of cattle, for littering them with straw, which was to be removed when soiled to the dunghill; and also advises the collection of all kinds of ashes, and the burning of weeds, shrubs, trees, and stubble, in fields; and the application of the incinerated matter as manure. The writings of this and other authors prove, that the ancients not only paid attention to the management of farmyard manure, but that they were well acquainted with the mode of preparing artificial and all ordinary composts. Columella says he is not ignorant that there are some farms in the country in which neither the dung of cattle nor of birds is to be obtained. However, he is a slothful husbandman who has no manure. He may, states the same authority, collect any kind of leaves, the cuttings of briars, and rakings of highways; he may cut ferns, and mix these with the cleanings of his courtyard; he may dig a hollow place such as was directed for the dunghill, and throw into it ashes, the dirt of the kennels, all kinds of straw, and everything that is swept from the house. Indeed, the various processes now followed by agriculturists to render the soil fertile, were known by the Romans. They incorporated light with heavy soils, and rendered them more porous; and although unacquainted with the theory of the operation, they may be said to have originated the principle of the modern process of subsoil-ploughing; for in some districts it was the custom every fifth or seventh year to dig as deep as the rain penetrated, and turn up the bottom of the mould, by which the corn-fields were said to be renewed, the particles of earth proper to the nourishment of the plants being supplied, to be carried downwards along with the rain. The practice of economising and employing farmyard manure and composts in general, may be said to have been transmitted from the Romans, with little change, to the beginning of the present century, varied only by the use and incorporation into composts of such articles as particular districts afforded. Thus chalk was employed in some places as a great adjunct to farmyard manure for turnips and all kinds of grain; in others, marl superseded lime; and along the sea-coasts, calcareous sea-sand, and sea-weeds, were in high repute. In other districts, where manufactures were established, the refuse materials, such as soap-waste, under the name of soap-ash, woollen rags, *et cetera*, were in common use. Later still, animal matters, such as fish and bone, and other dressings, were in demand.

Although by the foregoing one sees what knowledge even the Romans possessed of manures, still they were far behind the Chinese in their system of agriculture. The basis of their mode is, as so often reiterated by Liebig, *to return to the soil every ingredient that has been removed by a crop.* The result has been, that instead of the land becoming impoverished, it has augmented in fertility with a continually increasing population, since the time of Abraham or of the Egyptian Pyramids. All those means, says Liebig, which the German agriculturist considers perfectly indispensable for the increase of his produce, are not only quite unnecessary for the Chinese, *but without them* he produces crops more than double those of his Teutonic brother. No doubt other conditions exist in China different to Germany; some of them are Buddhists, and eat no meat, while here meat is partaken of for which fodder is required; but that is not the question—here principles are involved which must guide practice. The agricultural preceptors do not teach the planting of fodder with the view to obtain meat, but in order to have *dung;* and by this they prove that they do not understand a scientific law. In fixing a scientific principle, the first question is, not whether it is advantageous, but whether it be true? In scientific agriculture *dung* no longer exists. All the ideas conveyed by this word are now exploded. Like the word *phlogiston*, which became obsolete at the end of the last century, as long as it was not known what phlogiston was, it served as an aggregate term to bind together a number of unknown causes to render them comprehensible. After it was ascertained what phlogiston represented, the right ideas were substituted, and the explanation of phenomena became true and reliable. Wood does not burn otherwise than formerly, air is what it was, water moistens as before; but what immense progress the human race has made since the right conception of air, oxygen, and the process of combustion took the place of the word phlogiston? A similar, but greater and more blessed advancement, must follow from the right knowledge or perception of the nutritive process in plants and animals; and it is as absurd for a chemical teacher to explain phenomena by phlogiston, as it would be for the farmer to employ the word dung in explanation of any agricultural process; for, in the place of this word, which is now without meaning, the word manure or compost is now substituted, expressing that for each plant there are certain ingredients serving as food, from the great effect of which the phenomena must be explained.

Theory of Manures.—To understand the part which manures play in rendering soils productive, recourse must be had to the analysis of plants themselves. The composition of these will necessarily indicate the materials which must be supplied in order to promote their healthy growth. Now, when soils are submitted to the action of fire, it is found that there is an organic portion which burns off completely, and a residual one incapable of combustion, consisting of mineral substances. The same result follows the action of heat on plants. Healthy plants invariably contain a certain number of these mineral ingredients, and in fact always the same substances; the nature and quality, or the varying proportions of which, are ascertained by finding the composition of the ashes of the plants. The organic portion, dissipated by heat, consists mainly of the elements carbon, hydrogen, nitrogen, and oxygen, which produce by their union the various proximate principles of which plants are composed. The development of a plant, therefore, requires the presence of bodies capable of furnishing carbon, nitrogen, water or its elements, and the mineral matters which are likewise essential to vegetals. The latter ingredients can only be derived from the soil, but the supply of the elements which form the organic part may be quite independent of the soil. Lichens, which were at one time supposed to be destitute of roots, have been shown to be possessed of these organs with seemingly greater power than those of trees and herbs: for they are able to disintegrate and take up the necessary portions of the rocks to which they are attached, and fix them as a part of their constitution. Their organic constituents under these circumstances can come from only one source, namely, the atmosphere.

Origin of the Organic Portion of Plants.—As carbon, the essential ingredient of organic bodies, is in its separate state altogether insoluble in water, it is plain that this element must be presented to plants in such a form that it can be easily absorbed. This can readily be effected when the carbon is in the form of a complex compound quite soluble in water, or in the simple state of carbonic acid, a gas which is also freely dissolved by water. Hence have arisen two schools of vegetal physiologists—the one holding that organic substances which can be dissolved by water, are by its means conveyed through the rootlets of plants, and contribute directly to their nourishment equally with carbonic acid; the other holding that though such complex organic substances may pass in solution through the roots into the interior of plants, yet they in no way contribute to their nourishment, but must, previously to entering the plant, be decomposed into carbonic acid before they can be utilized. In other words, one school asserts that the carbon of plants is derived from soluble organic substances, as well as from carbonic acid; the other, that it is derived from carbonic acid *alone.* To the first school belong Saussure, Boussingault, Mulder, and Payen; to the second, Liebig and his followers.

The Humus theory of the Nutrition of Plants.—All plants and vegetal structures, after death, undergo decomposition by fermentation, and by a slow process of combustion, called by Liebig *eremacausis.* By these processes they lose carbon as carbonic acid, and are gradually converted into a dark-brown matter, which is known by the name of *humus.* Under this designation is included a variety of bodies, which have different chemical constitutions. Humus exists in larger quantities in virgin soils, and as such soils are noted for their fertility, the presence of this matter came to be regarded as the source of fertility of all soils. It was considered to be the principal nutriment of plants. The water of the soil, it was believed, dissolved the carbonic acid produced by the conversion of the vegetal fibres into humus, and those portions of humus soluble in water; and both of these, being absorbed by the roots of plants, contributed directly to their nourishment. Hence farmers added vegetal manure in large quantity to the soil, with the view of providing food for their intended crops. Want of space will not permit the discussion of the humus question. It will be sufficient to notice the objections brought against it by the supporters of the opposite views of the nutrition of plants. *First.* Springs of water arising out of the richest vegetal mould are quite clear, and contain no humus in solution. *Second,* Not the slightest ground exists for the belief that those substances called ulmin, humic acid, humin, *et cetera*, products of decomposition of vegetal matter by alkalies, exist in nature, in the form, and endowed with the properties, of the organic constituents of mould; and there is no proof that one of these exerts any influence on the growth of plants. *Third,* The experiments of Saussure, which are generally adduced in favor of the humus theory, only show that the quantities of soluble organic substances taken up by the roots of plants, are just in the proportion in which they would run through filters. Thus, sulphates of the alkalies, which percolate a filter faster than acetate or nitrate of lime, were also taken up in greater quantity by the roots of plants. Sugar dissolved in water filters more easily than gum, and much more so than humus extract;

plants took up twice as much gum, and four times as much sugar as humus extract. *Fourth*, Granting that water does dissolve certain organic matters as well as carbonic acid, and convey them into the interior of the plant, it does not follow that such organic matters contribute to their growth. The roots of plants may absorb all soluble matters, organic as well as inorganic, with which they come in contact, yet only such portions be retained as are necessary to their organism; the remainder being returned to the soil. Did this power of selection not exist, the quantity of mineral constituents in plants, for example, would soon become enormous. The soluble organic matter, with the surplus mineral matter, is again returned to the soil. *Fifth*, There is great probability that the roots of plants have the power of selection, for as yet, even in the outer cells of the rootlets, not a trace of humus extract has been actually discovered. The presence of a substance resembling humic acid found in some diseased plants, is no argument in favor of its general presence.

The second theory of the supply of carbon to plants, rejects altogether the intervention of soluble organic matters. Woody fibre in the soil, by the access of oxygen, gives rise to carbonic acid. If this carbonic acid be removed, and a fresh portion of oxygen be admitted, a fresh portion of carbonic acid will be formed. This process is slow, and the presence of water is necessary to its maintenance. Woody fibre in this progressive state of eremacausis, is called humus, and when the decay is complete, and there is no longer formed any carbonic acid by the access of oxygen, there is left a brown coaly-looking substance, which is mould. In every fertile soil there is, therefore, an atmosphere of carbonic acid surrounding every particle of decaying humus. This is dissolved by water in the soil, and at once absorbed by the roots of plants. By loosening the soil all round the roots, the access of air is accelerated, and a further portion of carbonic acid is the result. The roots, from the first moment of their formation, extract from the soil their proper nourishment, namely, the carbonic acid generated by the humus. As soon as the leaves have appeared, they also begin their functions by absorbing carbonic acid from the air. The quantity of this gas in the atmosphere, amounting to about one-tenth per cent., appears to be a trifling source of carbon. But when the immense mass of the air is taken into account, and it is recollected, that by the law of diffusion of gases, carbonic acid is in the same proportion in all parts, it can easily be shown by calculation that the atmosphere contains no less than three thousand and eighty-five billion pounds of carbon—*a quantity which greatly exceeds the weight of all the plants existing in the world.* This amount of carbon is, therefore, more than adequate for the growth of all plants, even if they were confined to this source of supply alone.

When a plant is fully developed, and the organs by which it obtains food from the atmosphere are formed, it may be said to be independent of the soil for its carbon. But as the functions of the organs of plants cannot be conceived to cease for a moment during their life; and as soils in which plants vegetate vigorously always contain moisture, holding in solution carbonic acid, either produced within the soil, or brought to it by rain from the atmosphere, it follows that plants during their life must constantly absorb carbonic acid by their roots as well as by their leaves. It is thus seen, that on the one hand, a plant when placed under peculiar circumstances can depend on the carbonic acid of the atmosphere alone for its carbon, and that it has an abundant supply of this element in the air; yet under the ordinary normal condition of vegetal life, the supply must come from the carbonic acid of the soil as well as the air.

SOURCE OF NITROGEN OF PLANTS.—The quantity of nitrogen present in plants is small when compared with their carbon, hydrogen, and oxygen. One hundred parts of hay, oats, and potatoes, when dried at 240°, contain respectively one and a half, two and a half, and one and a fifth parts of nitrogen. But, though existing in such small proportions, this element is one of the most important in the constitution of vegetal products which serve as food for animals; their value in the scale of nutrition rising with the quantity of nitrogen they contain. It has been a subject of considerable discussion of late years, whether the nitrogen of the air is not absorbed by plants, and contributes directly to their nourishment. In a memoir presented to the Academy of Sciences, VILLE affirmed that the nitrogen of the air is assimilated by plants. BOUSSINGAULT showed by a series of carefully-conducted experiments, that this supposition of VILLE was incorrect. A committee, of which CHEVREUL was reporter, was appointed by the Academy to investigate the point. They made a series of experiments which, they stated, resulted in favor of VILLE's views. Still later, BOUSSINGAULT reinvestigated the subject, and by a series of the most carefully-conducted experiments, appears to have settled the question; and though VILLE, by still more recent experiments, thinks his prior views confirmed, yet for the present the results obtained by the former lead to the conclusion, that nitrogen is not directly assimilated by plants. The nitrogen of plants can, therefore, be derived from only two sources, namely, from ammonia and nitric acid.

When a large quantity of rain water which falls after long dry weather, or melted snow is evaporated to dryness, with a little sulphuric or hydrochloric acid, the residue is found to contain ammonia, which can be detected by its peculiar odor, on the addition of a little slaked lime. This ammonia, which at all times exists in the air, is derived from the putrefaction of animal substances, and from numerous other sources, from which it is evolved chiefly as carbonate. It is very soluble in water; hence every shower of rain removes it from the atmosphere, which again receives a constant supply from the sources just stated. Ammonia is the last product of the putrefaction of animal bodies. But if this ammonia be placed under favorable circumstances, it undergoes eremacausis, or slow combustion. The oxygen of the air converts its hydrogen into water, and its nitrogen into nitric acid. There is another mode in which nitric acid may be produced, namely by the direct combination of its elements, nitrogen and oxygen, by means of electricity. This effect is often observed in thunder-storms. There is thus a constant supply of nitrogen from the atmosphere, in the form of ammonia and nitric acid. The amount present in a given portion of air is very small; but the total quantity which may be derived from this source in a given time is not inconsiderable, when it is recollected, that a generation of a thousand million men is renewed every thirty years; and thousands of millions of animals cease to live, and are reproduced, in a much shorter time.

The ammonia and nitric acid in solution in water in the soil, are at once absorbed by the roots of plants, and in both forms assimilated by their organs for the production of the nitrogenized matters which they contain. This fact has been proved by many observers. The juice of maples, birches, tobacco-leaves, when evaporated with lime, emits a quantity of ammonia. The evolution of ammonia from the juice of beet in the process of clarifying by lime, is familiar to every beet-sugar manufacturer. The tobacco plant, sunflower, Borago officinalis, Apium Graveolens, contain in their juices considerable quantities of nitric acid in the form of nitrates. The presence of nitrates in the sap of plants has been supposed to prove that the nitrogen of the nitric acid is not employed in the organism for the production of compounds containing that element. But this conclusion cannot be drawn from the presence in the juice of nitric acid, any more than from the presence of ammonia and carbonic acid. It only proves that these substances after absorption have not yet undergone decomposition and fixation in the plant, or that they exist as a surplus not required for its further development.

The employment of animal manures for those crops which are most important as food of animals, is a satisfactory proof that their nitrogen is derived from ammonia. An increase of animal manure gives rise not only to an increase in the number of seeds, but also in the proportion of those substances in them which contain nitrogen. One hundred parts of wheat grown on a soil manured with cow dung, a manure which contains the smallest quantity of nitrogen, afforded only 11·95 parts of gluten, and 62·34 parts of starch; whilst the same quantity grown on a soil manured with human urine, which is highly nitrogenized, afforded the maximum of gluten, namely, 35·1 per cent. In a subsequent portion of this article, the question of the supply of ammonia to plants will be again noticed.

In the foregoing remarks it is seen, that the conditions necessary for the production of the organic constituents of plants are moisture, and the presence everywhere of bodies to furnish carbon and nitrogen. The essential food of plants must not be one which is found in one place, and is absent from another. Wherever water is, there must be found these sources of carbon and nitrogen. No substances fulfil these conditions but carbonic acid and ammonia. Hence the whole theory of the nourishment of a plant, so far as the formation of its organic portions is concerned, consists in the constant supply of carbonic acid and ammonia, and as a substitute for the latter, nitric acid, from which carbon and nitrogen are assimilated.

The Inorganic Food of Plants.—Experience has shown that, however abundantly carbonic acid and ammonia may be supplied to plants, yet they cannot live upon these alone. Seeds sown in sand, and aspersed with water impregnated with carbonic acid and ammonia, arrive at a certain stage of growth, and then begin to droop and die. The inorganic matter left on burning a plant is as necessary for its growth as carbonic acid and ammonia. The bones, muscles, and blood of animals cannot exist without a constant supply of inorganic elements, and these must be derived ultimately from plants which form the food of graminiferous animals. Hence plants must store up within themselves inorganic constituents for the wants of animals, as well as for themselves. The number of these inorganic constituents is comparatively small. They are chiefly potassa, soda, lime, magnesia, oxide of iron, and silica, phosphoric and sulphuric acid, and chlorine. It is not known what particular part they play in the vegetal organism; but that they are essential is proved by the power which is conferred on plants of selecting such substances as are necessary for the growth of their different parts. Sea-water contains a large quantity of soda, and but a mere trace of potassa; yet some sea-weeds, as dulse, contain much potassa and little soda; thus proving that the plant has selected out of a mass of soda the potassa, which is necessary for the perfect structure of its seed.

In the first instance, the roots of plants may take up all substances in solution without selection. But this action is not one of simple imbibition as in the case of sponges. Liebig, in a recent memoir, maintains that the spongioles, in obtaining their supply of saline matter, exert a real decomposing action on certain ill-defined compounds, which the saline matter forms with the insoluble constituents of the soil. Those substances which are conveyed to plants in solution are retained in greater or less quantity, or are entirely rejected when not fit for assimilation.

Carefully-conducted experiments have proved, that on whatever soil grown, if a plant is healthy and ripens its seed, the quantity and kind of ash which it contains are, within certain limits, and with certain admissible variations, nearly the same. Further experiments have also shown, that the ash left by two different species of plants grown on the same soil, is never exactly the same. Thus silica, alkaline and earthy phosphates, form invariable constituents of the seeds of all kinds of grasses; and bulbous and tuberous roots are characterized by the large quantity of potassa and soda they contain. The different parts, too, of the same plant have variable proportions of inorganic matter. Such constituents, according to Liebig, appear to exist in the smallest quantity in those parts of a plant in which the process of assimilation is most active, as in the mass of woody fibre; and their quantity is greatest in those organs, the office of which it is to prepare substances conveyed to them for assimilation by other parts. Hence there is a larger quantity present in leaves than in branches, and more in the latter than in stems.

The quantity of ash left by the different parts of cultivated plants is seen by the following table:—

PROPORTION OF ASHES LEFT BY ONE HUNDRED POUNDS OF THE SEEDS, HUSKS, AND STRAWS, OF THE USUALLY CULTIVATED GRAINS.

	Grain	Husk.	Straw.
Wheat,	2·31 mean	——	5·39 mean
Barley,	2·54 "	——	5·86 "
Oats, without husk,	2·01 "	6·51 mean	6·14 "
Rye,	2·41 "	6·5 "	3·29 "
Indian corn,	1·3	——	4·54 "
Field beans,	3·0 "	——	5·0 "
Field peas,	2·7	Pod 7·1 ——	——
Vetches,	2·4	10·8	6·0 mean
Lentils,	2·06	——	5·38
Linseed,	4·2 mean	——	Flax 1·28 and 4·5
Hempseed,	5·6	——	Hemp 1·78 ——

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF THE DIFFERENT ROOT CROPS—NAMELY, OF CABBAGE, TOBACCO, *et cetera*, WHEN DRIED.

	Root.	Leaves.
Potatoes,	3·9 mean	21·5 mean
Turnip,	7·0 "	17·0 "
Carrot,	5·1	16·42
Parsnip,	4·3	15·76
Mangold-wurzel,	7·0	7·55
Cabbage,	—	22·00
Tobacco	—	23·08

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF THE GRASSES WHEN DRY.

Lucerne,	9·5
Red clover,	7·5
White clover,	9·1
Ryegrass,	6·0
Knot grass,	2·3
Holcus lanatus,	6·2
Poa pratensis,	6·2
Scripus,	2·3

PROPORTION OF ASH LEFT BY ONE HUNDRED POUNDS OF DIFFERENT KINDS OF TREES.

	Wood.	Seed.	Dried leaves.
Larch,	0·33	5·0	6·0
Scotch fir,	0·16	4·98	2·5
Pitch pine,	0·25	4·47	3·15
Beech,	0·35	—	5·4
Willow,	0·45	—	8·2
Birch,	0·34	—	5·0
Elm,	1·88	—	11·8
Ash,	0·5	—	—
Oak,	0·21	—	4·5
Poplar,	1·97	—	9·2
Sugar-cane,	1·45	—	9·4
Hop,	5·00	Flowers. 10·90	16·3

When the composition of the ash thus left by plants is examined, several important points are ascertained. It is seen that though silica is not always wanting for the grain of the corn-bearing plants and grapes, yet that it is absolutely necessary to, and may be said to be the characteristic mineral ingredients of their stems. In the ash of the grain of wheat it amounts to one per cent., whilst in the ash of its straw the quantity varies from forty to eighty per cent.

Phosphoric acid is the characteristic ingredient of the seeds of plants. It forms about one-half of the ash of the grain of the different cereals, when burnt with their husks, but is seldom present in any considerable quantity in their ripe straws.

As the ash of the stems of cereals is characterized by silica, so the ash of the stalks of leguminous plants, and the tops of the potato and turnip, are remarkable for the quantity of lime they contain.

Root crops have also their characteristic mineral ingredients. Potassa and soda, which are present to the extent of thirty per cent. in the ash of cereals, and about forty per cent. in the ashes of beans and peas, amount to about fifty to sixty per cent. in the ash of the turnip and potato. Thus larger quantities of the alkalies are present in roots than in other crops raised for human food.

The following table shows the amount of essential inorganic ingredients contained in one hundred parts of the ashes of the commonly cultivated plants :—

	Potassa and soda.	Lime.	Magnesia.	Phosphoric acid.	Sulphuric acid.	Silica.
Wheat-grain,	33	3	12	50	0·25	1
Barley "	22	3	7	39	0·10	27
Oats "	26	6	10	44	11·0	3
Rye "	34	5	10	50	1·0	0·4
Indian corn,	33	1	16	45	3·0	1·0
Rice,	30	1	12	53	—	3·0
Beans,	44	6	8	38	1·0	1·0
Peas,	44	5	8	34	4·0	0·51
Wheat-straw,	13	7	4	3	6·0	65·0
Barley "	7	10	3	3	2·0	71·0
Oat "	29	8	4	3	3·0	48·0
Rye "	18	9	2	4	1·0	65·0
Maize "	35	8	7	17	—	28·0
Rice "	14	—	5	1	4·0	74·0
Bean "	28	36	7	12	2·0	11·0
Pea "	17	40	8	8	7·0	10·0
Red clover,	36	33	8	8	3·0	7·0
Potatoes, root,	57	2	5	13	14·0	4·0
Turnip, "	47	14	5	8	14·0	8·0
Beet, "	50	9	5	8	2·0	10·0
Carrot, "	54	17	1·3	16	10·0	3·0
Cabbage,	32	21	6·0	12	22·0	0·74
Potato tops,	44	17	7·0	8	7·0	4·0
Turnip "	34	23	3·0	9	13·0	1·0

JOHNSTON has made elaborate calculations in his agricultural lectures, to show the enormous amount of mineral constituents removed from the soil by cultivated plants. Only a few examples, by way of illustration, need be taken :—

Mineral Constituents removed per acre of Wheat.—If the produce of a field of wheat be taken at the rate of twenty-five bushels per imperial acre, weighing sixty pounds a bushel; and if the straw averages twice the weight of the grain, then the quantity of inorganic matter carried off the soil by the crop will be, per acre :—

	Pounds.
In one thousand five hundred pounds of grain at two per cent. of ash,	30
In three thousand pounds of straw at six per cent.,	180
Total,	210

The composition of the matter thus carried off, according to the mean of analyses of ashes given in the table, will be, in pounds:—

	Grain.	Straw.	Total.
Potassa,	7·15	22·44	29·59
Soda,	2·73	0·29	3·02
Lime,	0·85	12·09	12·94
Magnesia,	3·63	6·89	10·52
Oxide of iron,	0·20	2·35	2·55
Phosphoric acid,	15·02	5·54	20·56
Sulphuric acid,	0·07	10·49	10·56
Chlorine,	—	1·97	1·97
Silica,	0·35	117·94	118·29
	30·00	180·00	210·00

Mineral Constituents removed per acre by a Crop of Barley.—If the produce of an imperial acre of barley amount to forty bushels, each weighing fifty-three pounds, and if the straw averages one-fourth more than the weight of the grain, then the proportion of inorganic matter removed from each acre by a crop of barley, will be—

	Pounds.
In two thousand one hundred and twenty pounds of grain at two and a half per cent. of ash,	53
In two thousand six hundred and fifty pounds of straw at six per cent. of straw,	160
Total,	213

The composition of this ash will be found by the table to consist of—

	Grain.	Straw.	Total.
Potassa,	7·24	10·29	17·53
Soda,	4·32	0·92	5·24
Lime,	1·39	15·53	16·92
Magnesia,	3·97	5·25	9·22
Oxide of iron,	0·79	1·35	2·14
Alumina,	0·12	2·26	2·38
Phosphoric acid,	20·74	5·02	25·76
Sulphuric acid,	0·05	2·66	2·71
Chlorine,	0·02	1·58	1·60
Silica,	14·36	115·14	129·50
	53·00	160·00	213·00

Mineral Constituents removed per acre by a Crop of Turnips.—A good crop of turnips varies from twenty to forty tons of bulbs per imperial acre. If twenty tons be taken as an average crop, and if the tops, which always vary much in the proportion they bear to the clean bulbs, be assumed as equal to one-third of the weight of the bulbs, the inorganic matter carried off by a crop of roots and tops will be as follows:—Twenty tons of bulbs contain two tons of dry matter, leaving seven and a half per cent. of ash, or about three hundred and forty pounds. Six tons and a third of tops contain one thousand eight hundred and fifty pounds of dry matter, leaving seventeen per cent. of ash, or about three hundred and ten pounds. Bulbs and tops thus remove in all six hundred and fifty pounds of mineral matter, having the annexed composition, in pounds:—

	Bulbs	Tops	Total
Potassa,	142·66	88·82	231·48
Soda,	17·31	16·76	34·07
Lime,	46·24	72·14	118·38
Magnesia,	18·16	9·58	27·74
Oxide of iron,	4·35	2·67	7·02
Phosphoric acid,	25·77	28·80	54·57
Sulphuric acid,	46·24	38·81	85·05
Chlorine,	12·24	49·75	61·99
Silica,	27·03	2·67	29·70
	340·00	310·00	650·00

Mineral Constituents removed per acre by a Crop of Hay, consisting of one ton of rye grass, and half a ton of red clover:—

	Pounds.
Potassa,	38·22
Soda,	12·05
Lime,	44·45
Magnesia,	7·09
Oxide of iron,	0·58
Phosphoric acid,	15·12
Sulphuric acid,	9·20
Chlorine,	4·06
Silica,	78·23
	209·00

The total mineral constituents removed from the soil by this four years' rotation of crops, will be, in pounds:—

	Grain.	Straw.	Bulbs	Tops.	Hay.	Total.
Potassa,	14·39	32·73	142·66	88·82	38·22	316·82
Soda,	7·05	1·21	17·31	16·76	12·05	54·38
Lime,	2·24	27·62	46·24	72·14	44·45	192·65
Magnesia,	7·60	12·14	18·16	9·58	7·09	54·57
Oxide of iron,	1·11	5·96	4·35	2·67	0·58	14·67
Phosphoric acid,	35·76	10·56	25·77	28·80	15·12	116·01
Sulphuric acid,	0·12	13·15	46·24	38·81	9·20	107·52
Chlorine,	0·02	3·55	12·24	49·75	4·06	69·62
Silica,	14·71	233·08	27·03	2·67	78·23	355·72
	83·00	340·00	340·00	310·00	209·00	1282·00

This table is highly important, as showing the enormous quantity of soluble minerals removed from soils by cultivated crops. If the crops were removed from the ground, and no means were taken to return to the soil in some form the mineral constituents thus constantly taken off, the inevitable consequence would ultimately be *utter sterility*.

Application of Manures.—The facts adduced in the preceding pages tend to show what is the real nature of manures, and in what manner they act. They are the food of plants; hence the necessity of understanding, in the first instance, the mode in which plants are nourished. Plants must be furnished with matter to build up their organic and inorganic portions. Complex organic matters, as has been stated, do not nourish plants, until decomposed into carbonic acid, water, and ammonia. These substances exist in the air; this source might, therefore, be trusted for their supply, but a double source of supply, from air and soil, undoubtedly causes greater activity in a given time in vegetation. Inorganic constituents can come from the soil alone. Of the two kinds of food of plants, the gaseous and inorganic, which it may be necessary to add to a barren soil, by far the most important and indispensable is the latter.

The various facts already discussed, and the essential points connected with the application of manures, cannot be better summed up, than in the words of LIEBIG in his Principles of Agricultural Chemistry.

In the shape of agricultural produce of a field, the entire amount of those constituents which have become ingredients of plants is removed from the soil. After a series of years, and a corresponding number of harvests, the fertility of the soil or field diminishes. The change which is found to have taken place in the composition of the soil after harvest, is the probable cause of its diminished or lost fertility. By means of solid and liquid manure, or the excreta of men and animals, the lost or diminished fertility of the land is restored. Solid or farmyard manure consists of decayed vegetal and animal matters, which contain a certain proportion of the constituents of the soil. The excrements of men and animals represent the ashes of the food consumed, and which has been derived from the supposed soil. The urine contains the soluble, the solid excreta the insoluble constituents of the soil derived from the crops used as food, and reaped from the soil. By adding these to the soil, it recovers those constituents which have been removed from it in the crops.

Thus the restoration of its original composition is accompanied by the restoration of its fertility. It is therefore certain that one of the conditions of fertility in a soil, is the presence in it of certain mineral constituents. A rich fertile ground contains more of these than a poor barren one does.

Vegetal and animal matters, and animal excreta, when in the soil, undergo putrefaction and slow oxidation. The nitrogen of their nitrogenized constituents is changed in the process of putrefaction and decay into ammonia, and a small part into nitric acid, which is the product of the oxidation or decay of ammonia. There is every reason to believe that nitric acid can replace ammonia, as a source of nitrogen to plants. In animal manures, therefore, not only are plants supplied with the mineral substances which the soil must yield, but they are also supplied with those parts of their food which the plant obtains from the atmosphere. The latter supply is a clear addition to that which the air at all times affords.

The solid and liquid parts of the food of plants contained in the soil must enter the roots in solution in water, or, in the case of those substances not soluble in pure water, in water containing carbonic acid or some salt of ammonia. Hence animal manures, undergoing decay in the soil, render the air and water which pass through it richer in carbonic acid and salts of ammonia. They thus not only supply plants with a certain amount of their mineral and atmospheric food, but also provide them with those substances—carbonic acid and ammoniacal salts—which are the most indispensable for the introduction into the vegetal organism of the mineral constituents, which, by themselves, are insoluble in water, and this to a larger amount in the same time than could be effected without the co-operation of decaying organic matter. The mineral constituents which all plants, without exception, require for their nutrition, are phosphoric acid, sulphuric acid, the alkalies, lime, magnesia, and iron. Some important genera require silica. Those which grow on the seashore and on the sea require chloride of sodium, soda, and iodides of metals. In some genera, the alkalies may in part be replaced by lime and magnesia, or these latter by the alkalies. All these substances are included in the term mineral food of plants; carbonic acid and ammonia being termed the atmospheric food.

From some recent experiments respecting the capacity of soils for absorbing the soluble constituents of manure, LIEBIG has been led to a new theory respecting the nutrition of plants, and which is quite opposed to the foregoing view. The inference deducible from the Baron's experiments is as follows:—That land plants do not receive their food from a solution of the ingredients already present in the soil, but that they abstract or absorb it *directly from the soil itself*, through the joint agency of water *and of a force inherent in the roots*.

The different substances necessary to the growth of a plant, or the different articles of their food, are all of equal value; that is to say, if one out of the whole number be absent, the plant will not thrive. The soils which are proper for the cultivation of all sorts of plants, contain all the mineral constituents necessary for them. But of two soils containing equal quantities of these mineral ingredients, one may be considered rich or fertile, and the other poor or barren, if in the former case they are present in a form soluble in water, and in the latter are insoluble. All soils adapted for culture contain the mineral food of plants in these two states. The quantity of the soluble ingredients can be increased from the insoluble, in other words, the soil made more productive by mechanical means. This process is called weathering, or fallow; the insoluble minerals being disintegrated by the aid of carbonic acid, oxygen, and water. Hence stagnant water in the soil—undrained fields—which excludes the air from access to the insoluble compounds, is an obstacle to this process of weathering. Land in which the necessary mineral constituents are not present in any form, cannot be rendered fertile by fallow or by ploughing.

As different kinds of plants require for their development in some cases the same mineral substances, but in unequal quantities, a soil may become barren for any one kind of plant, when by a series of crops one only of these constituents, as for example, soluble silica has been so far removed that the remaining quantity is no longer sufficient for a crop; but it may still contain sufficient mineral constituents for another kind of crop which does not require soluble silica. A third sort of plant may thrive on the same soil after the second, if the remaining mineral constituents suffice for a crop of it. Upon this fact depends the rotation of crops.

The nutritive substances necessary to the life of a plant must act together within a given time, if the plant is to attain its full development in that time. The absence or deficiency, or the want of available form in one necessary constituent, renders the others which are present ineffectual, or diminishes their efficacy, and the soil is rendered barren for all those crops to the life of which that one constituent is indispensable; but fertility is communicated if that one substance be added in due quantity, and in an available form. The supply of more atmospheric food—namely, carbonic acid and ammonia —by means of ammoniacal salts and humus, than the air can furnish, increases in a given time the efficacy of the mineral constituents present in the soil. In a soil rich in the mineral food of plants, the produce cannot be increased by adding more of the same substances. In a soil rich in the atmospheric food of plants, rendered so by manuring, the produce cannot be increased by adding more of the same substances.

From land rich in mineral constituents, there may be obtained in one year, or for a series of years, by the addition of ammonia alone, in its salts, or of humus and ammonia, rich crops, without in any way restoring the mineral substances removed in these crops. The duration of this fertility depends on the supply of the available mineral constituents existing in the soil. The continued use of these manures produces sooner or later an exhaustion of the soil. If after a time the soil is to recover its original fertility, the mineral substances extracted from it by the crops in a series of years must be again restored.

These admirable propositions furnish the key to the application of manures. The continued fertility of a soil for all kinds of crops, depends on the constant return to it of *all* the mineral constituents removed by the different crops. If a great increase in one crop has been effected by the application of one manure alone—for example, of phosphate of lime, or of ammonia —this only proves that all the other ingredients necessary to that crop have been present in sufficient abundance in the soil. The agriculturist would not be warranted by the success of this one experiment in repeating it too often, or the infallible result would be the ultimate exhaustion of his land. No single mineral substance, in however large quantities, can confer *permanent* fertility. This result can only be attained by the combination of all those mineral salts found in the ashes of plants, or by the use of a compost, such as carefully prepared farmyard manure, which contains in itself these different ingredients.

Here perhaps may be the proper place to notice, that the views of the nature of manures advanced by LIEBIG have been combated by LAWES and GILBERT, who have endeavored to show by a series of experimental results, that this so-called mineral theory of LIEBIG is an entire failure as a guide to the use of manures in practical farming. In some respects their views may be said to be diametrically opposed to those of LIEBIG. As a rule the latter holds, that plants when abundantly provided with their mineral constituents in an available form, may get their carbon and nitrogen from the air, though it does not follow that this source alone is to be trusted to for these ingredients; the former think that their experiments warrant them in concluding, that minerals supplied to wheat crops in much greater quantity than equivalent to those taken off in the increased produce, were only available so long as there was a liberal provision of nitrogen in the soil; that when this artificially-supplied nitrogen was exhausted, the minerals remained inactive and useless; that in the very cases where minerals gave an increased produce, in the well-defined limit to their action which is indicated, there is further proof of the necessity of an artificial supply of nitrogen in the soil for the increased production of corn, and the incapacity of the mineral supply to yield any increase, excepting when nitrogen is thus provided. They further concluded from their experiments, that there is a fallacy in supplying to plants a manure founded on the per centage composition of their ashes: for in the case of the turnip, which shows, both in the leaf and in the bulb, a proportion of alkalies to phosphoric acid of from four or five to one, it might be thought that alkalies were, therefore, the more appropriate and special manure for turnips, whereas common practice has determined in favor of phosphoric acid, and their own experiments proved that the addition of alkalies to superphosphates on turnips did not increase the return.

LIEBIG, in his recent work on the Principles of Agricultural Chemistry, has clearly proved that the conclusions of these gentlemen are based on the most palpable fallacy of selecting for their experiments a portion of land which, so far from being in a practically and agriculturally exhausted state, was by the showing of their own experiments, still so rich in mineral constituents as to have yielded, though unmanured throughout, in the seventh year a crop which exceeded by seventy-seven pounds of grain and five hundred and ninety-nine pounds of straw that of the first year. The conclusion drawn by them from their results, that nitrogenized manures are peculiarly adapted for the culture of wheat, is true only for their own land under the given circumstances, namely, containing a sufficiency of available minerals, and would entirely mislead the practical farmer if he applied it to other land of different quality, and placed in different preliminary conditions. For it can be proved, as LIEBIG states, in tho same way, and by facts equally decisive, that ammoniacal salts alone, in thousands of wheat fields, do not in the smallest degree increase the produce; and that in thousands of other such fields, these salts do increase the produce for a year or two; and that then a further application of them to the same land is found to be utterly without effect; that salts of ammonia increase the produce only if the mineral constituents be present in the soil in due quantity, and in an available form, by rendering those minerals more soluble, and accelerating their action in a given time. Hence the use of ammoniacal salts alone tends rapidly to exhaust a soil, and if used by themselves without any mineral manure, no cultivation whatever can be permanently kept up.

In the opinion of LIEBIG, the experiments of LAWES and GILBERT, so far from disproving the mineral theory, afford, on the contrary, the strictest and most satisfactory proof of its truth. The reader is referred to LIEBIG's able work for a clear and distinct view of what is really his mineral theory, and to a paper by the same author in defence of his views, in the seventeenth volume of the Journal of the English Agricultural Society.

Farmyard manure is taken as the type of manures, because it contains all the constituents removed from the land, and again restored to it in a form in which they can be made rapidly available. The carbonic acid and salts of ammonia produced by its decomposition, cause water to dissolve more rapidly the mineral constituents. Compounds of ammonia would thus seem to have two actions in the nourishment of plants, namely, *First*, As a source of nitrogen; *Second*, As a solvent for certain important mineral constituents of the soil.

An artificial mixture can be theoretically compounded to take the place of farmyard manure, but it must contain all its mineral constituents. The agriculturist must return to the land whatever has been removed from it; for it has been laid down as a rule, that no part of the constituents of a rich soil can be removed without making compensation, but at the cost of sooner or later impairing its fertility.

It is not to be supposed from the preceding, that practical empirical experiments with special manures are to be altogether condemned as useless. They are, on the contrary, highly valuable under certain conditions. The error lies in elevating the practical results into general laws. Experience has shown, for example, that nitrogenized manures have produced large crops of wheat, and superphosphate of lime has had the same effect with turnips. The experimenters, forgetting to inquire whether these results are universally true, or true only under certain conditions, have emphatically pronounced nitrogen and superphosphates to be *the* manures for these crops. Other experimenters have come forward and shown that nitrogenized manures in their hands have not always had good results, and bones in the hands of others have not answered at all, either for turnips or anything else.

These contradictory conclusions embarrass the practical farmer, but the man of science sees that the difficulty lies in having taken these special results for general truths. His science has taught him, that there is a law more general still for the successful cultivation of wheat and turnips under all circumstances, namely, that along with nitrogen and phosphates, they must have *all* their mineral constituents provided for them. He is able thus to show, that the application of nitrogen and that of phosphates are mere special conditions for the successful cultivation of these two crops, which can only hold good when the more general and universal conditions are fulfilled. Instead of altogether rejecting the practical results obtained by others, he endeavors to ascertain if the failure of the special rule, in any given case, does not arise from the land not fulfilling the conditions of the more general law.

Rules for the application of Artificial Manures.—The following rules have been given by W. Hannam, as useful in carrying into effect the judicious application of artificial manures:—

In all mixtures designed for application in autumn or winter, the ammonia or nitrogen should be supplied in a form that would as far as possible prevent its operating too quickly—for example, it would be preferable to supply the nitrogen in union with other organic matter, as in rape-dust, bones, woollen rags, partially decomposed blood, guano, mixed with charcoal, gypsum, *et cetera*, rather than in the shape of salts of ammonia, which are so speedily soluble:

That all winter dressings of artificial manure should be mixed in the soil:

That all mixtures in which the ammonia exists in a saline form, should be applied as a spring top-dressing upon the crop, if possible in wet weather during the third or fourth week of April:

That all mixtures containing organic matter rich in ammonia, as rape-dust or guano, if applied with spring crops, should be harrowed in immediately; and if applied as a top-dressing, should be used only in wet weather:

That spring top-dressings, which contain organic matter, should be applied earlier than those purely saline:

That mineral manures which contain their phosphates and alkalies in the most soluble state, should be applied in spring crops:

That where a heavy saline dressing is required in spring, upon wheat, potatoes, or grass, it is advisable to apply it at two distinct periods about a month apart, as in April or May.

In a recent paper, just received from Baron LIEBIG, and which contains numerous experimental data, the good effects of chloride of sodium, nitrate of soda, and salts of ammonia are shown to depend, not so much on their intrinsic value, as upon their capacity of dissolving large quantities of phosphate of lime, thus rendering this important salt easily conveyable to the roots of the plants.

Absorbent power of soils for Manures.—At the time these rules were given, the absorbent powers of soil were not then known, and precautions were supposed to be necessary in the application of manures, which experiment has since shown to be superfluous.

THOMPSON first pointed out the power possessed by soils in arresting salts of ammonia, and WAY has extended the same observation to all the mineral constituents which serve as food of plants. He found that, without exception, the bases of the alkalies and alkaline earths were removed from their acids, and retained by soils; the acids, such as sulphuric and hydrochloric passing away in solution in combination with lime. There was one remarkable exception in the case of phosphoric acid, which never passed away like sulphuric acid, but was retained by the soil, though presented to it in the form of a soluble alkaline phosphate. Nitric acid, on the other hand, now and much employed in agriculture, was found to pass rapidly away. This acid, when in combination with potassa, soda, or ammonia, was found to give up these bases, and to pass off in combination with lime. In prosecuting his inquiries to find out what constituents of soil possessed this extraordinary power, he ascertained that it was due to clay alone. It is not a mere power of absorption, as is the case with charcoal, but a chemical action. It does not appear, however, that the whole mass of clay acts, but portions containing silicate of lime, which, in contact with the alkaline salts, gives up a portion of its lime to their acids, and retains their bases as double silicates. Whether or not this is the true explanation, the fact is certain, that clay is the absorbing material. Hence, sandy and gravelly soils not possessing a sufficiency of clay, might be expected to be less retentive of manure. The experience of all farmers proves this fact; such sandy and gravelly land being said by them not to hold manures. On such soils, manures require to be applied more frequently and in smaller quantities than in stiffer clay soils, which have the power of retaining the manure for several crops.

A knowledge of this property of clay explains the fertility attending the application, as is practised in Norfolk, of clay to sandy soils. From some recent experiments and analyses, Liebig doubts whether the clay is the only absorbing material. In the Editor's opinion, the *physical condition* of the soil must have something to do with it.

In the case of ammonia, the supply to the soil is not derived alone from the manures, or the ammonia of the air brought down by rain; but absorption of this gas goes on continuously from the atmosphere by contact alone. Liebig, in 1846, caused the analysis of twenty soils to be made in his laboratory, from which he ascertained the enormous amount of ammonia really present in every soil. One acre of the most unfruitful soil taken, to the depth of only ten inches, contained more than a hundred times, and one acre of fertile soil, as much as from five hundred to a thousand times more nitrogen than is required for the heaviest crop of wheat, or than is given to it in the most liberal supply of manure.

If the experimental results of Way be correct, it would appear that unnecessary alarm was felt a short time ago, that the system of tile-draining, which was so universally adopted with the happiest effects to agriculture, would ultimately tend to exhaust the soluble mineral ingredients of the soil.

In his paper on the composition of land-drainage water, Way has, by a series of carefully-conducted analyses, found that the substances which exist in drainage water in largest proportion are those which are most abundant in the soil, namely, lime and magnesia, soda, and sulphuric acid; and that, with the exception of nitric acid, none of the essential mineral food of plants is found in any quantity. If 42·4 per cent. of the annual rain pass through the soil, and the latter be taken at 25 inches, the quantity of drainage water from an acre of land would amount to about two hundred and forty thousand gallons. Even where the land is very highly manured, he shows that this large quantity of water removes from the soil only inconsiderable quantities of the most important mineral ingredients of soils, namely, potassa and phosphoric acid. The quantity of ammonia carried off is very small; but nitrogen in the form of nitric acid, especially in highly manured land, is to be found in large quantity in the water of land drainage. Voelker showed that clay soils exert this action on complex organic mixtures, such as the drainings of dunghills, as well as on simple salts. From the most highly mixed manuring substances, not only ammonia from the ammoniacal salts, but potassa, phosphoric acid, and all the essential ingredients of the food of plants, are all removed from solution in water, and retained in the soil.

These experimental results are fundamental facts of the utmost importance to agriculture. They explain the advantage of drainage, by showing that the manure which would be carried off the surface of the undrained land into the water-courses, is carried down by the water which is passing into the drains of a drained field, but is separated from solution by the soil through which it percolates. They show that the best mode of applying manures is that which causes the most uniform distribution of it, namely, as a liquid. For if salts of ammonia, when once applied to the soil, combine with it and remain fixed, water would seem to have no further power of uniformly distributing them, and hence the frequent irregularity of crops in manured fields. The fear has hitherto been, that by too early an application of manures to the land before the crop, there was a risk of loss, by evaporation and by rain. This is true to some extent for sandy soils, on which, it appears, the true guiding principle should be, for the manure to be applied frequently and in smaller quantities at once. The retentive power of clay, on the other hand, may be fairly trusted to keep all that is bestowed upon well-drained clay soils.

Classification of Manures.—Manures may be divided into two great classes, namely, general and special.

General manures include all mixed substances, whether of an animal or vegetal origin, which contain all the constituents necessary to plants for luxuriant growth. Such manures confer permanent fertility on a soil.

Under this class may be ranged—Farmyard Manure, Guano, Night-Soil, Sewage Manure, *et cetera.*

Special manures are those substances which contain only one or more of the constituents necessary to the growth of plants. They cannot confer permanent fertility on the land, but on the contrary, their exclusive and continued use tends to render it ultimately sterile, by enabling particular crops to remove more rapidly and largely those ingredients which are actually in the soil. To this class belong bones, blood, woollen rags, horns, fresh rape-cake, sea-weeds, gas-liquor, salts of ammonia and of the alkalies and alkaline earths, *et cetera.*

It would be quite out of place in an article of this kind, to discuss at length the various substances used as fertilizers. It will be sufficient to take from these two classes one or two examples of the most commonly-employed manures, and to give under each the principal points connected with their theory, management, and applications, from which the principles connected with the application of other manures may be inferred.

General Manures.—*Farmyard Manure—History.*—The first attempt to restore fertility to the soil must have been by the use of the excrement of animals, and must date from an early period of the history of mankind. The art of husbandry, and the preparation of mixed manures for their fields, occupied much the attention of the Romans. Their writers inculcate the formation of two manure heaps, one to receive the fresh dung, the second for the old manure, which was applied to the field after being kept a year. Their manure was recommended to be placed in a hollow to collect moisture, and to be covered with straw to protect it from the weather. These good rules were forgotten during the long period which succeeded the extinction of Roman civilization. It is only of late years that science has been brought to bear on this subject, and with that success which is its invariable accompaniment. The study of the composition, and of the chemical metamorphoses that farmyard manure undergoes, has enabled scientific men to suggest the best means of collecting, preserving, and applying it.

Theory of the action of Farmyard Manure.—It has long been an opinion of the practical farmer, that nothing can be a complete substitute for farmyard manure. This opinion is to a considerable extent justified by analysis, for it contains, with the exception of a portion of carbon and hydrogen, all the materials which have been removed from the soil by plants. It is formed for the most part of cows' dung, pigs' dung, and straw, mixed and trodden together. Where green crops are extensively grown and many cattle kept, cow dung forms a great proportion of the manure. The composition and value of farmyard manure will, therefore, vary much with the feeding and the animals. Thus, the manure of cattle fed on turnips is inferior to that of cattle fed on oil cakes; the manure of horses fed on straw and hay, is much poorer than that of horses fed on corn; the compound manure which has an excess of cattle excrement is less powerful than one with an excess of the dung of the horse; the compound manure which contains no night-soil, is less fertilizing than one with a proportion of it. An analysis of one specimen of farmyard manure cannot be taken as a general expression of its composition, which varies with the circumstances above stated. The only process by which an approximative idea may be formed of the fertilizing powers of a given quantity of farmyard manure, is to observe the kinds of animal excrement it contains, and the proportions in which they are mixed with each other, and with vegetal matters.

Farmyard manure which is either quite fresh, or has undergone so little fermentation as to retain its litter in an undecomposed, and but partially broken state, is known by the name of *long dung*. When it has been thoroughly fermented, so as to have been changed into a rotten powdery or saponaceous mass, or is so free from litter as to consist almost entirely of solid excrement, it receives the name of *short dung*. Much controversy has existed among farmers, as to the relative merits of these two forms. An examination of the chemical changes which have taken place in this process, throws some light on these controversies. KOERTE found by experiment, that one hundred loads of fresh dung become reduced by fermentation and exposure as follows:—

	Loads.
In 81 days 100 loads were reduced to	73·3
In 285 " " "	64·4
In 384 " " "	62·5
In 499 " " "	47·2

In sixteen months the quantity had been reduced to less than one half, and the most valuable salts lost.

The reduction of weight of farmyard manure depends on two causes, namely, the elimination of gases by fermentation, and the loss of soluble matters by drainage. The latter, the least feared, is by far the most serious source of loss. The former has been shown by VOELKER to be not so destructive as was formerly supposed.

By making a thorough mixture of the litter, and dung of fresh or long dung, VOELKER obtained a sample for analysis, and for experiments with fermentation. By comparing the composition before and after fermentation, he arrived at some valuable conclusions.

Fresh farmyard manure, composed of horse, pig, and cow dung, about fourteen days old, and on which no rain had fallen, was found to consist, in round numbers, of two-thirds of water and one-third of solid matters.

COMPOSITION OF FRESH FARMYARD MANURE, COMPOSED AS ABOVE STATED, AND FOURTEEN DAYS OLD.

	In its natural fresh state.		In its dry state.	
Water,		66·17	—	—
Soluble organic matter,		2·48	—	7·33
Containing nitrogen,	0·149	—	0·44	—
Equal to ammonia,	0·181	—	0·53	—
Soluble inorganic matter—ash composed of—				
Soluble silica,	0·237	—	0·703	—
Phosphate of lime,	0·299	—	0·884	—
Lime,	0·066	—	0·185	—
Magnesia,	0·011	—	0·033	—
Potassa,	0·573	—	1·695	—
Soda,	0·051	—	0·153	—
Chloride of sodium,	0·030	—	0·089	—
Sulphuric acid,	0·055	—	0·035	—
Carbonic acid and loss,	0·218	—	0·772	—
		1·54		4·55
Insoluble organic matter,		25·76	—	76·15
Containing nitrogen,	0·494	—	1·46	—
Equal to ammonia,	0·599	—	1·77	—
Insoluble inorganic matter—ash composed of—				
Soluble silica,	0·967	—	2·865	—
Insoluble silica,	0·561	—	1·659	—
Oxide of iron, and alumina with phosphates,	0·596	—	1·404	—
Containing phosphoric acid,	0·178	—	0·528	—
Equal to bone earth,	0·386	—	0·822	—
Lime,	1·120	—	3·335	—
Magnesia,	0·143	—	0·424	—
Potassa,	0·099	—	0·294	—
Soda,	0·019	—	0·077	—
Sulphuric acid,	0·061	—	0·210	—
Carbonic acid and loss,	0·484	4·05	1·722	11·97
		100·00		100·00
Whole manure contains ammonia in free state,	0·034	—	0·10	—
" " in form of salts,	0·088	—	0·26	—

This analysis of a fair average specimen of fresh farmyard manure, so far as an average can be taken of this substance, is instructive. It shows that farmyard manuro is a perfect and universal manure, because it contains all the constituents which are required by the commonly-cultivated crops to bring them to perfection, and in states of combination which appear to be especially favorable to their luxuriant growth. It explains fully the slow action of fresh dung when compared with the effects of well-rotted manure; because the former contains only one-eighth of soluble matters as compared with the insoluble, whilst in the latter this quantity of soluble is much increased by fermentation, as will presently be seen. In this small soluble portion, the most important fertilizing substances are present.

The proportion of nitrogen in one hundred parts of the soluble organic matter, as compared with the insoluble, is as 6·04 to 1·92. The most valuable salts present in considerable quantities are silicates of potassa and phosphate of lime.

The remarkable fact of the presence, in the watery solution, of phosphate of lime, usually considered an insoluble compound, is explained by the observation of Wöhler, that bone-dust, moistened with a little water. in the course of a few days yields to water a considerable quantity of phosphate of lime, and this solubility rapidly increases with the putrefaction of the gelatine of bones. Hence, wherever earthy phosphates exist with organic matter, water will invariably dissolve a portion, progressively with the decomposition of the organic matter by fermentation. This fact is of the utmost importance to agriculture.

The effect produced on manure by fermentation is well seen by analysis. A well-mixed sample of rotten dung. of dark-brown color, at least six months old, and which was produced under the same circumstances as the fresh manure, was found to have the following composition:—

COMPOSITION OF WELL-ROTTED MANURE, SIX MONTHS OLD, CONSISTING OF MIXED HORSE, COW. AND PIG DUNG.

	In its natural fresh state.		In its dry state.	
Water,	—	75·42	—	—
Soluble organic matter,	—	3·71	—	15·09
Containing nitrogen,	0·297	—	1·21	—
Equal to ammonia,	0·360	—	1·47	—
Soluble inorganic matter, or ash, composed of—				
Soluble silica,	0·254	—	1·035	—
Phosphate of lime,	0·382	—	1·554	—
Lime,	0·117	—	0·476	—
Magnesia,	0·047	—	0·193	—
Potassa,	0·446	—	1·816	—
Soda,	0·023	—	0·140	—
Chloride of sodium,	0·037	—	0·151	—
Sulphuric acid,	0·058	—	0·235	—
Carbonic acid and loss,	0·106	1·47	0·380	—
				5·98
Insoluble organic matter,	—	12·82	—	52·15
Containing nitrogen,	0·309	—	1·26	—
Equal to ammonia,	0·375	—	1·53	—
Insoluble inorganic matter, or ash, composed of—				
Soluble silica,	1·424	—	5·79	—
Insoluble silica,	1·010	—	4·11	—
Oxides of iron and alumina, with phosphates,	0·947	—	3·85	—
Containing phosphoric acid,	0·274	—	1·11	—
Equal to bone earth,	0·573	—	2·41	—
Lime,	1·667	—	6·78	—
Magnesia,	0·091	—	0·37	—
Potassa,	0·045	—	0·18	—
Soda,	0·038	—	0·15	—
Sulphuric acid,	0·063	—	0·29	—
Carbonic acid and loss,	1·295	6·58	5·26	26·78
		100·00		100·00
Whole manure contains ammonia in free state,	0·046	—	0·189	—
" " " form of salts,	0·057	—	0·232	—

An examination of these two Tables shows that, during the fermentation of dung, the quantity of both soluble organic and soluble mineral matters rapidly increases; and that the proportion of ammonia and of phosphate of lime in these soluble matters also rapidly augments. Thus one hundred parts of dry soluble organic matter from fresh dung contain 6·14 of nitrogen, whilst one hundred from rotten dung contain 8·02, and the phosphate of lime is nearly doubled. The proportion of organic matter decreases as the fermentation goes on, but the loss is in carbonic acid and other non-essential gases. There is apparently no serious loss of ammonia by evaporation, as is commonly supposed. Direct experiments have shown that, in the cold, no ammonia is given off from the surface of farmyard manure, and that a considerable amount of heat is necessary for this purpose. Now, as this occurs only in the interior of the heap when the fermentation is active, the liberated ammonia, in passing through the outer layers of decaying organic matter at a lower temperature, is arrested. This fact was proved by Voelker by the analysis of fresh manure made into a heap, and left for six months. The amount of dry organic matter was found to have diminished from nine hundred and sixty pounds to six hundred and ninety; but the total amount of nitrogen at the commencement was 18·23 pounds, and at the end of six months 18·14, or nearly the same.

The practical result of these changes by fermentation is, that, weight for weight, well-rotted farmyard manure is richer in soluble fertilizing constituents than fresh dung, and contains more readily available nitrogen, and, therefore, is more immediate and energetic in its action on vegetation.

It appears that, up to a certain point, the efficacy of farmyard manure is increased by a well-regulated fermentation, during which the loss of really valuable constituents is trifling. But there is a danger of serious loss if the fermentation is pushed too far and the manure heap is frequently turned, whilst there is great heat developed by this fermentation.

Another, and a far more serious loss, is incurred by keeping manure too long unprotected from the weather, not, however, by the volatilization of ammonia, but by the removal of salts of ammonia, soluble nitrogenized organic matters, and valuable mineral salts by rain; well-rotted dung being more readily affected than fresh. This loss is great when the manure is kept in heaps, and the deterioration is still more rapid when the method of making manure is by animals kept in open yards. The dark-colored fluids from manure heaps, which are too frequently allowed to run into the next ditch, are but concentrated solutions of their most valuable constituents: they not only contain the valuable potassa salts and ammonia, but also phosphate of lime, a constituent brought into solution by the process of fermentation.

The following table shows the loss sustained at successive periods in twelve months, by two thousand eight hundred and thirty-eight pounds of manure put up in a heap in the usual way, and exposed to the weather:—

	When put up.			
	November 3, 1854.	April 30, 1855.	August 23, 1855.	November 15, 1855.
Weight of manure in pounds,	2,838	2,026	1,994	1,974
Amount of water in the manure,	1877·9	1336·1	1505·3	1466·5
Amount of dry matter in the manure,	960·1	689·9	488·7	507·5
Consisting of—				
Soluble organic matter,	70·38	86·51	58·83	54·04
Soluble mineral matter,	43·71	57·88	39·16	36·89
Insoluble organic matter,	731·07	389·74	243·22	214·92
Insoluble mineral matter,	114·94	155·77	147·49	201·65
	960·10	689·90	488·70	507·50

The amount of nitrogen and its equivalent of ammonia in the preceding soluble and insoluble organic matter is the following:—

SOLUBLE ORGANIC MATTER.				
Containing nitrogen,	4·22	6·07	3·76	3·65
Equal to ammonia,	5·12	7·37	4·56	4·26
INSOLUBLE ORGANIC MATTER.				
Containing nitrogen,	14·01	12·07	9·38	9·38
Equal to ammonia,	17·02	14·65	11·40	11·39
Total amount of nitrogen in the manure,	18·23	18·14	13·14	13·03
Equal to ammonia,	22·14	22·02	15·96	15·75
The manure contains ammonia in free state,	0·96	0·15	0·20	0·11
The manure contains ammonia in the form of salts, easily decomposed by quicklime,	2·49	1·71	0·75	0·80
Total amount of organic matters,	801·45	476·25	302·05	268·96
Total amount of mineral matters,	158·15	213·65	186·65	—

Management of Farmyard Manure. — The foregoing experiments teach that a certain amount of fermentation is good for farmyard manure, because it renders the fertilizing ingredients more soluble, and their effect more immediate. For the establishment and continuance of fermentation, a certain amount of heat, air, and moisture is necessary. These conditions are fulfilled when the latter is not in excess, and the excrement has been yielded by cattle fed on tolerably rich and succulent food. If the litter is in excess and but little excrementitious matter present, or not well mixed throughout with the litter, fermentation does not take place through the whole mass. Even when there is abundance of excrement, and fermentation has fully commenced, it is sometimes arrested by deficiency of moisture, and the interior of the heap presents, if no remedy is applied, a white appearance of dead, inert manure. This phenomenon is known under the name of fire-fanging. The prevention of this defect lies in the care that is taken to mix the excrement thoroughly on first collecting the manure; and if there is a deficiency of natural moisture, in adding water from time to time. The remedy for it when present, is to turn the heap over, soak it with water, and mix it with horse-dung, or any animal offal that can be obtained. When manure has been once properly mixed and placed in heaps, which ought not to be more than three or four feet high, it should be left to itself undisturbed until carted out for use. Some farms, however, produce so large an amount of manure that it is a matter of convenience and economy to remove it during winter to the borders of the fields where it is to be applied. In these cases the manure should be stirred as little as possible when taken from its original place of deposit, and when emptied from the carts at the new heap.

The great loss to be dreaded in manure piles is, as has been seen, from the rain. The drainings from manure heaps being much more valuable than the urine of animals, it is of the utmost importance to protect the heaps from the action of rain, and to collect the fluids which escape from them, which might be either applied as fluid manure, or, in smaller establishments, returned to the manure heaps. It might be advisable to incur the expense of covering with hurdles and straw, or with clay, such manure heaps as are placed in the fields. In these heaps the soluble salts are, in dry weather, continually brought by capillarity to the surface, only to be washed away by the next fall of rain.

Application of Farmyard Manure.—In old practice, a large dose of from thirty to fifty tons was given per acre, and not repeated till the land was nearly exhausted. The modern and improved practice is to give a moderate quantity, and repeat it often. Quantities, varying from ten to fifteen tons, are used according to the nature of the soil, the quality of the manure, and the kind of crop. It has been recommended to spread and plough it in, immediately after being deposited from the carts, on the supposition that it suffers great loss by evaporation. If the experiments of VOELKER and of WAY be correct, and there seems to be no reason to doubt their accuracy, this notion is quite false. The results of these gentlemen would seem to indicate the best mode of application to be, to spread the manure as evenly as possible on the surface of the ground, at a time when it is not saturated with moisture or bound up with frost, but in a season of frequent showers. The soluble organic and mineral matters would, in the course of ten days or a fortnight, according to the amount of rain, be washed into and *retained* by the soil, and the insoluble matters could then be covered up by the plough. The old method of depositing the manure on the field in heaps, and leaving it so for a length of time, is a very bad practice. The soluble matters are washed into the ground under and immediately adjoining to the heaps, and cannot afterwards be evenly distributed by rain through the soil, hence the result is irregularity in the crops of such fields.

Night-Soil and Urine.—Night-soil is in general a very rich manure, but its offensive smell has prevented it from being generally used. This exhalation may, however, be removed by various substances, such as charcoal, a charred mixture of vegetal matter and clay, *et cetera.* In the vicinity of large towns it is dried and manufactured in various ways into a portable manure, which is sold as *poudrette*, dried night-soil, *et cetera.* In China it is mixed with clay, and sold under the name of *taffo.* FORTUNE, in his wanderings in China, gives an amusing account of the extreme care exhibited by the Chinese in collecting, preparing, and applying night-soil.

BERZELIUS found the composition of fresh fæces to be—

	Centesimally
Water	73·3
Organic matter,	25·5
Salts,	1·2
	100·0

In general, human excrement contains three-fourths of its weight of water, and its composition and consequent value varies with the food, and the age and health of the individual. The following analysis of this substance by WAY shows that it contains all the fertilizing constituents necessary for different crops:—

ANALYSIS OF DRIED HUMAN FÆCES.

	Composition of the ash.	Composition of the dried excrement.
Organic matter,	—	88·52
Insoluble silicious matter,	12·79	1·48
Oxide of iron,	4·66	0·54
Lime,	14·98	1·72
Magnesia,	13·48	1·55
Phosphoric acid,	37·17	4·27
Sulphuric acid,	2·10	0·24
Potassa,	10·40	1·19
Soda,	2·83	0·31
Chloride of sodium,	1·59	0·18
	100·00	100·00
Nitrogen per cent.,		5·00

Human Urine.—Human urine varies with the age, health, and food of the individual. It has been calculated that the average quantity voided in twenty-four hours by each member of a community is about three pounds. According to BECQUÉREL, the composition of urine in round numbers is, in a thousand parts:—

Water,	970·5
Solid constituents, 29·5 parts, consisting of—	
Urea,	13·5
Uric acid,	0·5
Fixed salts,	7·5
Organic salts,	8·5
	1000·0

The composition of the solid matter of evaporated urine was found by WAY to be as follows:—

	Composition of the ash.	Composition of the solid dry matter.
Organic matter and salts of ammonia,	—	67·54
Insoluble silicious matter	0·28	0·09
Oxide of iron,	0·14	0·05
Lime,	1·89	0·61
Magnesia,	1·49	0·47
Phosphoric acid,	14·31	4·66
Sulphuric acid,	1·43	0·46
Potassa,	5·64	1·83
Soda,	none	none
Chloride of potassium,	16·65	5·41
Chloride of sodium,	58·17	18·88
	100·00	100·00
Nitrogen per cent.,		19·43
Equal to ammonia,		23·60

When the total quantity of excrement and urine voided in twenty-four hours is taken into account, it is found that the latter is the most valuable. If the quantity of fæces for one individual for twenty-four hours be taken at one and a quarter pounds, and the quantity of urine at three pounds, the amount of nitrogen in each would be as follows:—

		Containing		
		Dry matter Grains	Salts Grains.	Nitrogen. Grains.
Solid excrement voided in twenty-four hours,	1,750 grains—1¼ pounds	437·5	21·0	26·25
Urine voided in twenty-four hours,	21,000 grains—13 pints	619·5	158·0	125·0

These analyses show how important it is to collect and add to the manure heap the excrement of men, which, in the proportion of valuable agricultural constituents it contains, far exceeds that of other animals.

Sewage Manure.—Sewage water may be considered as consisting of the solid and liquid excrements of a town population, with all the waste materials from manufactories and private houses which rain is capable of removing. That such a liquid must necessarily possess fertilizing properties is seen by turning to the analysis of human excrement already given. But when the supply of water to each individual is taken in addition to the rain daily passing through the drains, it has been estimated by Way that the solid matter of the urine and fæces passed in twenty-four hours by one individual, is mixed with fourteen hundred times its weight of water. If only the insoluble matter of the sewage were to be separated by filtration, it would be necessary to filter nearly three thousand tons—more than half a million of gallons—to obtain from it one ton of dry manuring matter. This enormous amount of liquid constitutes the real difficulty in the way of the application of sewage liquid to agricultural purposes; still even this difficulty is simply mechanical, since it follows from Liebig and Way's experiments, that, no matter how dilute a fertilizer may be, when applied, all its valuable constituents are retained by the land. The Chinese system seems to confirm the foregoing, as they prefer using their manures in a highly diluted form. Two modes of applying sewage manure have been proposed—the first, directly by irrigation; the second, by precipitating the solids and making use of them.

Where a natural fall exists for the outlet of the drains, the first plan has been most successfully carried out in various places. The rent of a meadow near Portobello, in the neighborhood of Edinburgh, was by this means raised from a few shillings to twenty-five pounds per acre. Various plans are now in agitation to carry away by a system of pipes the sewage of towns, and deliver it at a distance for agricultural purposes.

For effecting the second object—namely, the precipitation of the solids—various substances have been proposed. Among the most important of these are charcoal, lime, sulphate of lime, clays burnt and unburnt, the salts of alumina, and of zinc and iron, the compounds of magnesia, burnt magnesian lime-stone, and certain silicates. By none of these bodies are all the valuable fertilizing constituents precipitated, and many of them have little or no action at all on these substances. A good process for extracting at a moderate price the valuable constituents of sewage water is, therefore, still a desideratum.

GUANO.—Historical Notice.—This name is given to the accumulated fæcal matter of sea-fowl, and is derived from the Peruvian word *huana*, signifying manure or dung. There is scarcely anything more remarkable in the history of agriculture than the introduction into Great Britain of guano as a manure. The old faith in farmyard manure was so firmly established, that the new fertilizer was received with utter distrust. The report of its constant employment as the sole manure with the most marked success by the natives of the country from which it was imported, the results of trials with it by eminent Englishmen at home and elsewhere, obtained so little attention from the agricultural world generally, that in 1840 no greater quantity than twenty casks of it were imported. In 1841, the Earl of Derby—then Lord Stanley—introduced it to the notice of the public at the dinner of the Liverpool meeting of the Royal Agricultural Society of England. From this time it came rapidly into use; and, at the present moment, agriculturists have gone to the other extreme, and appear to think that they cannot get on without it. The quantities imported into Britain during the first five years after its fair introduction to agriculturists, and whilst it was slowly making its way with them, compared with the importations of the last five years, will show how enormously this substance has risen in repute:—

	Tons.		Tons.
1841,............	1,733	1853,............	123,166
1842,............	13,094	1854,............	235,111
1843, ...	4,056	1855,............	143,136
1844,............	81,902	1856,............	191,501
1845,............	220,914	1857,............	288,362

The deposits of guano longest known, and for some time supposed to be the only ones, are those on the islands and sea-boards of Peru, between the thirteenth and twenty-first degrees of South latitude. The Peruvians are known to have made use of this substance as a fertilizer from the twelfth century. Their soil, which consists of sand and clay, and is naturally most barren, was enabled by the use of guano to produce year after year abundant crops of grain.

The Chincha Islands, which afford the best guano, are, according to Dr. Ure, three in number, and lie in one line from North to South, about half a mile apart. Each island is from five to six miles in circumference, and consists of granite covered with guano, in some places to a height of two hundred feet, in successive horizontal layers, each layer being from three feet to ten inches in thickness, and varying in color from light to dark-brown. No earthy matter whatsoever is mixed with this mass of excrements. In some of these islands, however, the deposit does not exceed three to four feet in thickness. The total quantity of guano estimated to be on these islands by M'Intosh, in his report to the Admiralty, was eight million six hundred thousand tons. According to the Peruvian survey, the quantity is double of this—namely, eighteen million two hundred and fifty thousand tons. Dr. Kinahan, in his paper in the Journal of the Royal Dublin Society for July, 1856, gives fifteen to twenty million tons; whilst others estimate it so high as from one hundred to one hundred and fifty million tons. From a rough estimate made by Mr. Walton, it would appear that the deposit of guano in Peru continues by the yearly addition of a fresh quantity of excrement amounting to about thirty thousand tons, which, however, does not all become available. Since the demand for guano has so increased, other localities have been searched, and supplies have been obtained from other and widely-separated regions. The coasts of Chili, Bolivia, Patagonia, Cuba, Labrador, Australia, and the isles of Ichaboe, Malaya, Augra, Peguena, and near the Cape of Good Hope, and of Kooria Mooria, near the coast of Arabia, have furnished supplies of greater or less magnitude, and of very varying qualities. It is highly probable that deposits of this substance will be found in every region much frequented by sea-fowl, and that further stores will yet be opened up when closer investigations have been made of the many uninhabited islands of the Pacific Ocean.

Fertilizing Power of Guano.—Guano owes its fertilizing power to its being a well-tempered mixture of nearly all the essential ingredients necessary for the nourishment of all cultivated crops. Its properties are particularly due to the large quantity of phosphates and ammonia which it contains, and these in a concentrated form. In the best guano—such as the Peruvian—there is present a considerable portion of alkaline phosphates, so that in itself guano combines all the good properties possessed by different manures separately. It contains soluble phosphates and salts of ammonia ready to be at once carried in solution in water into the roots of plants, and a further supply of these substances in a less soluble form, but which, by the aid of decomposition, and by the carbonic acid of the soil, are gradually dissolved and made available in proportion to the wants of the growing plant. There is only required the soluble silicates so necessary to the stems of the cereals, and which must be derived from some other source.

If the value of a manure be calculated, as is done by BOUSSINGAULT, according to the amount of nitrogen it contains, NESBIT estimates that one ton of good Peruvian guano is equal to

33½ tons of farmyard manure.
21 tons of horse dung.
38½ tons of cow dung.
22½ tons of pig dung.
14½ tons of mixed human excrements.

From the form in which the mineral constituents exist in guano, it is a manure peculiarly fitted for application in known quantities to the immediate wants of the growing crop.

It is not intended to convey by this, that the amount of mineral constituents to be removed by a given crop is to be calculated, and the exact corresponding amount of mineral matter in the guano to be added. As the roots of the growing crop are not likely to find *all* the substances added to the soil, a considerably greater quantity of mineral matter is actually employed than is likely to be removed by the crop. With this allowance the agriculturist is able to regulate his supply to the demand of the crop, and to go to no greater expense than what he may deem necessary for the existing wants. The materials are in a form in which they can be dissolved and made use of by the one growing crop; and if only added to the land in sufficient quantity for that one crop, no effect can be looked for in the succeeding crop.

The quantity of guano usually applied per acre varies from two to five hundredweight. It is applied directly as a top-dressing, spread broad-cast by hand over the surface, or in compost with other substances, either broad-cast or in drills, and buried by the plough. From its caustic nature, guano should not be placed in contact with the seed. In the case of wheat it may be sown broad-cast over the young plants in wet weather, and then harrowed in. With grass, clover, and such seeds sown broad-cast, it may be applied ten days before the seed, the land being immediately harrowed and allowed to absorb the manure. For turnips and other drilled crops, when used as an auxiliary to farm manure, it has been recommended to be sown broad-cast over the drills before they are split by the plough, to cover the farmyard manure in the furrows; the guano is thus mingled above the manure with the earth in which the turnip seed is to germinate. Perhaps, as has been recommended by NESBIT, it would be preferable to apply two-thirds of the guano broad-cast and one-third in drill with the seed. For this purpose the guano must be mixed with four to six times its weight of the ashes of wood or peat charcoal. The guano and ashes are then mixed in alternate layers by the spade or a sieve, and, after being well turned and mixed, left for eight days, and, finally, thoroughly incorporated by sifting; it is then fit for use. Great care must be taken that, in the drill, this mixture fall below the seed, and that the latter be protected by the intervention of an inch or two of soil.

Analysis of Guano.—Guano is a very complex mixture, containing urate, oxalate, and phosphate of ammonia, earthy phosphates, soluble alkaline salts, and organic matter. The analysis of such a compound is attended with some labor. As the value of guanos, however, depends on the quantity of ammonia, phosphates, soluble and insoluble, and alkaline salts which they contain, a very simple analysis is quite sufficient for agricultural purposes.

The guanos brought from different localities may be ranged under two heads—the ammoniacal and the phosphatic. The Peruvian is the type of the former, and is valuable for the large quantity of ammonia which it eviscerates. The Bolivian or Saldanha Bay may be taken as the type of the phosphatic class, which contains a small proportion of ammonia, with large quantities of earthy phosphates.

The composition of the different kinds of guano more generally imported, is the following:—

The composition of the Peruvian is the average of seventy-eight analyses made by WAY.

COMPOSITION OF PERUVIAN GUANO.

	Centesimally.
Moisture,	13·67
Organic matter and salts of ammonia,	52·05
Earthy phosphates,	22·78
Alkaline salts containing 3·34 phosphoric acid, and equal to 6·89 soluble phosphate of lime,	9·67
Sand, *et cetera*,	1·83
	100·00
Ammonia per cent.,	16·52

A variety of Peruvian guano, under the name of Angamos guano, is also met with in the market. It is the freshly-deposited fæcal matter of birds, is richer than Peruvian guano in ammonia, and brings a higher price. Only a few cargoes of this substance are annually obtainable. Its composition is subjoined:—

	Centesimally.
Moisture,	10·5
Organic matter and salts of ammonia,	62·5
Earthy phosphates,	17·0
Alkaline salts,	7·5
Sand, *et cetera*,	5·2
	100·0
Ammonia per cent.,	21·1

ANALYSIS OF THE CHIEF PHOSPHATIC AND OTHER GUANOS—AVERAGE COMPOSITION FROM SEVERAL ANALYSES.

	Ichaboe; earlier importations.	Ichaboe; recent importations.	Saldanha Bay.	Patagonian.	Bolivian.	Chilian.	Kooria Mooria.
Moisture,	27·3	20·0	20·0	25·0	10·0	20·4	18·1
Organic matter and salts of ammonia,	34·3	24·4	14·9	18·3	21·7	18·6	12·4
Earthy phosphates,	30·3	20·4	56·4	44·0	51·5	31·0	42·7
Alkaline salts,	5·0	6·2	5·8	2·1	14·1	7·3	4·2
Carbonate of lime,	—	—	—	—	—	—	4·1
Sand, *et cetera*,	3·1	29·0	2·9	10·6	2·7	22·7	18·5
	100·0	100 0	100·0	100·0	100·0	100·0	100·0
Ammonia per cent.,	7·3	6·0	1·47	2·5	4·5	5·47	2·05

The following is a simple method for analysing guano, which gives sufficiently accurate results for commercial and agricultural purposes. The sample of guano, which ought to be taken from different bags, is to be well mixed, and about two pounds of this taken for analysis. If there are lumps in the sample, these are to be finely pounded, and the whole repeatedly passed through a sieve so as to get a uniform mixture. To determine the moisture, about fifty grains are to be dried at 212° till they cease to lose weight.

For Ammonia.—If the sample is rich in ammonia, about twenty grains, and, if poor, about fifty grains are taken, a few drops of hydrochloric acid added to prevent the loss of this alkali, which takes place in some guanos on exsiccation, and then dried at 212°, and burnt with soda-lime, which must also be previously desiccated and cooled immediately before use. The mixture is introduced as rapidly as possible into the combustion tube. No appreciable loss of ammonia occurs if the substances are well dried before mixing. For ordinary purposes, sufficiently exact results are obtained by simply evaporating the chloride of ammonium on a water bath to dryness. One part of this salt represents 0·315 of ammonia.

Fifty grains of the sample are burned at not too high a temperature, till they cease to lose weight. The loss in weight represents the moisture, organic matter, and ammoniacal salts.

After being weighed, the ash is digested in warm water, filtered, and washed two or three times. The residue, dried and weighed, represents matters insoluble in water; the loss represents the soluble alkaline salts, which generally consist of chlorides and sulphates; and in the case of the better class of guanos, such as Peruvian, also of alkaline phosphates. The aqueous filtrate may be divided into two portions, in one of which the phosphoric acid is determined by the addition of sulphate of magnesia, ammonia, and chloride of ammonium. One hundred parts of the precipitate, dried, ignited, and weighed, contain 64·30 parts of phosphoric acid. It will be sufficient to evaporate almost to dryness about one ounce of the second portion of the fluid, and to test for the presence of potassa, soda, sulphuric acid, and chlorine.

The ash left by the water is treated with dilute hydrochloric acid, filtered, and the residue washed and weighed. The undissolved portion is sand, clay, and, in recent or adulterated guanos, gypsum. By boiling the residue for half an hour in a concentrated solution of carbonate of soda, filtering, washing the residue, and then acting on it in the filter with dilute hydrochoric acid, and again washing, the gypsum will be tolerably well removed from the sand and clay. The difference in weight represents the sulphate of lime. If gypsum is present, the portion of this dissolved in the watery solution is apt to be reckoned as soluble alkaline salts: correction should be made for this.

The hydrochloric-acid solution is precipitated by ammonia, and the earthy phosphates filtered, dried, and weighed. The precipitate obtained by ammonia when added to the sand and gypsum, ought to be nearly the same as the weight of ash left by the water. When this is not the case it is due to impurities, such as carbonate of lime, and the loss of weight corresponds to the quantity of this substance present.

Adulterations of Guano.—From its high price there is no manure so subject to adulterations as guano. The substances generally made use of for this purposo are sand, marl, limestone, clay, powdered bricks or tiles, gypsum, chloride of sodium, *et cetera.* One or more of these substances mixed with the strong smelling guanos, such as the Ichaboe, and by the addition of a few feathers, form altogether so prime-looking an article, that even experienced buyers are deceived by it. Chemical analysis alone can reveal the deception.

Various simple experiments have been proposed to enable inexperienced unscientific persons to say whether a given sample of guano is or is not sophisticated. The conclusions are drawn from tho specific gravity, the color of the ash, effervescence with an acid, *et cetera.* But such conclusions would only be correct for certain specimens of guano—not for all.

The following are simple means by which adulterations of genuine Peruvian guano can be detected.

When burnt it leaves a perfectly white ash, when pure; but if adulterated with sand, marl, *et cetera*, the ash is more or less of a brown, or reddish-brown color. On the addition of strong acetic acid or hydrochloric acid to the ash, there is no effervescence if pure, but strong effervescence if adulterated with marl or chalk.

On the Mode of Estimating the Money Value of Guano.—If the money value of a manure is to be calculated, it is only necessary to ascertain the prices at which its valuable ingredients can be purchased in the market. Agricultural chemists have endeavored to fix the market value of the different constituents of manures, but their scales are not uniform. The following table gives the value per ton of the different constituents of manures, according to four different agricultural chemists:—

	Way.	Hodges.
Ammonia,	£56 0 0	£56 0 0
Insoluble phosphates,	7 0 0	7 0 0
Soluble phosphates,	32 13 0	25 0 0
Potassa,	30 16 0	20 0 0
Alkaline salts,	1 0 0	1 0 0
Organic matters,	1 0 0	0 10 0
Gypsum,	0 0 0	0 0 0

	Nesbit.	Anderson.
Ammonia,	£60 0 0	£56 0 0
Insoluble phosphates,	8 0 0	7 0 0
Soluble phosphates,	24 0 0	28 0 0
Potassa,	0 0 0	20 0 0
Alkaline salts,	1 0 0	1 0 0
Organic matters,	1 0 0	0 0 0
Gypsum,	1 0 0	0 0 0

Discarding the decimals below 0·5, reckoning those above 0·5 as an additional unit, and leaving out of the calculation the value of the organic matter and potassa, the price of Peruvian guano would be the following, supposing the market value of its constituents to be as above stated according to Way:—

		Value per ton.	Total.
Moisture,	13·67	—	—
Organic matter,	52·05	—	—
Earthy phosphates,	23·0	£7 0 0	£161
Soluble phosphates,	7·0	32 13 0	228
Alkaline salts,	10·0	1 0 0	10
Potassa and the alkalies,	3·0	30 0 0	90
Ammonia,	16·50	56 0 0	924

Special Manures.—*Bone Manure History.*—Bone manure is said to have been long in use in hothouses in Germany, whence it was first introduced into England. Arthur Young in his Northern Tour, 1770, mentions, that in the neighborhood of Sheffield bones were a very common manure for grass. About the same period, bones were used for turnips and arable crops in the limestone district of Yorkshire, and Lincolnshire. Like guano, it was at first received with distrust, and only after many years took its place in agriculture as one of the most valuable special manures known. In 1823, the declared value of bones imported into Great Britain was only fourteen thousand three hundred and ninety-five pounds sterling, and in 1837, it was two hundred and fifty-four thousand six hundred pounds sterling. In 1815, the quantity imported into Hull was about eight thousand tons, in 1833, it was seventeen thousand five hundred tons, and in 1835, was twenty-five thousand seven hundred tons. The chief supply comes from Germany and Russia, and from the coasts of the Baltic. The earlier form of using this manure was as calcined bones, or when uncalcined, they were broken in pieces and distributed at the bottom of the manure heap, to undergo decomposition. In 1840, an increased impetus was given to the employment of bones, by the recommendation of Liebig to render it more readily soluble and available to plants by the action of sulphuric acid.

Theory of the Action of Bones.—Bones consist of two portions, organic and inorganic, in the proportion of about thirty-three of the former, to sixty-seven of the latter. The chief portion of the inorganic part, the phosphate of lime, called in agricultural language, bone earth, is supposed by Berzelius, to be a peculiar basic compound of eight equivalents of lime, united to three of phosphoric acid, and having the following per centage composition:—

	Centesimally.
Lime,	51·12
Phosphoric acid,	48·88
	100·00

Mitscherlich and others, however, regard it with more probability as a compound of three equivalents of lime and one of phosphoric acid, its composition being

	Centesimally.
Lime,	53·86
Phosphoric acid,	46·14
	100·00

The thirty-three per cent. of organic matter yield, by decay, about five and a half per cent. of ammonia. Hence fresh bones are valuable as a manure for the large quantity of earthy phosphates they contain, and the considerable amount of ammonia they are capable of yielding.

Liebig's axiom is, that no special manure can be of any use if the soil does not possess the other ingredients necessary to the crop. Bones are, therefore, only valuable when these conditions are fulfilled. Under such circumstances they have been proved to be the manure for turnips.

As bones furnish only two substances to crops, science as well as experience indicates that they are more likely to be useful when used as auxiliaries—for example, with farmyard manure, *et cetera*. At all events, that this is true, when bones are to be used for some years, may be deduced from the mineral theory. A striking instance of this fact occurred in Nottinghamshire. The soil was supposed to have become deficient in bone earth, and as the first applications produced very good results, it was supposed that by the constant repetition of a larger quantity increased fertility would follow. These hopes were disappointed, until it was shown by other experiments that other mineral constituents were necessary. By the addition of these, the accumulated stores of dormant bone earth immediately began to develop wonderful effects. This is but another instance of the truth of the mineral theory of Liebig.

The rapid fertilizing effects of bones depend on the state in which they are presented to the roots of plants. When buried in the entire state, they undergo decomposition very slowly. Hence it has been found necessary to make them more rapidly available by grinding them, in which state they undergo fermentation readily, are reduced to powder, and thus made more soluble; or the ground bones, instead of being allowed to ferment, are first acted on by sulphuric acid, by which they are converted into a soluble form, known under the name of superphosphate.

Steamed Bones.—Mr. BLACKALL found, that bones submitted to high-pressure steam decomposed rapidly in the soil. This method was recommended by him as a good process for agricultural purposes. Others have found it necessary to crush the bones after steaming, to render them fit for application. In this method there is a loss of nitrogen in the gelatin dissolved out by the steam.

Fermented Bones.—Another mode for the decomposition of bones, so as to render them more readily available, is by fermentation. The process consists in mixing the bones with earth, ashes, farmyard manure into a compost, and leaving them to ferment. Certain substances, such as peat-ashes, have been supposed to cause this action more rapidly. Mr. PUSEY showed in 1847, that by mixing bones with an inert substance, such as sand, and watering the heap, and then closely covering up the whole with earth, putrefactive fermentation was generated.

The process would be still more effectual, and produce a better mixture, if instead of sand, wood or peat ashes were added to the ground bones, and urine employed to moisten the mass instead of water. As there might be a loss of ammonia by the heat generated, it would be advisable to spread a layer of sulphate of lime between the bones and the covering of clay; or to mix two or three hundredweight of gypsum with every ton of bones.

Dissolved Bones.—Superphosphate of Lime.—This term is bestowed on the commercial mixture of bones and sulphuric acid rendered dry by various absorbents. The mixture consists essentially of neutral phosphate of lime, which is scarcely soluble in water; biphosphate of lime, which is quite soluble; and sulphate of lime.

If the composition of the neutral phosphate of lime be taken according to BERZELIUS, as

Phosphoric acid,	48·5
Lime,	51·5
	100·0

and the biphosphate, as containing

Phosphoric acid,	71·5
Lime,	28·5
	100·0

Then one hundred parts of neutral phosphate can be converted into sixty-eight parts of biphosphate by the removal of thirty-two parts of lime by sulphuric acid. But as the materials from which superphosphate is manufactured, namely, bones, coprolites, *et cetera*, are not pure neutral phosphates of lime, a larger quantity of sulphuric acid is required. The average composition of raw bones may be taken as the following:—

Water, fat, and cartilage,	48
Phosphate of lime, with a little phosphate of magnesia,	46
Carbonate of lime,	4
Alkaline chlorides and sulphates,	2
	100

If the whole of this is to be converted into biphosphate, the following quantities of sulphuric acid, of specific gravity 1·70, would be required:—

	Pounds
To neutralize the carbonate,	4
To convert the whole phosphate into biphosphate	25
Total,	29

Provided the bones are finely ground, and the acid and crushed bones well mixed, theory would indicate that, by employing sulphuric acid to the extent of one-third of the weight of the raw bones, the whole of the bones would be converted into biphosphate.

Superphosphate of Lime from Coprolites.—Coprolites have been extensively used as a substitute for bones in the manufacture of superphosphates, but they do not produce so good an article. They are very hard, and unless well ground, which is frequently not the case, they are not readily acted on by acid; moreover, a larger quantity of acid is also necessary, as they contain a larger proportion of carbonate of lime.

Practical Rules for the Manufacture of Superphosphate of Lime.—The essential condition in this manufacture is, to reduce the bones or coprolites to be acted upon to as fine a state as possible before applying the acid. The sulphuric acid, mixed with twice its bulk of water, or further diluted with due regard to the subsequent drying, is added by degrees to the crushed materials, which are kept constantly stirred so as to bring all parts into contact with the acid. The absorbents, which are either ashes, mould, bones, coprolites, or some such materials, are then to be added, till the mass is sufficiently dry. Where machinery cannot be had, the following modification of a plan proposed by Mr. PUSEY has been found useful, on a small scale, for the conversion of eighty bushels of bones. A circular wall, in height about two feet, is formed of ashes. The space inclosed is about ten feet. The crushed bones are passed through a fine quarter-inch sieve. The coarser particles are laid flat in the centre, and the finer are placed round the ring, close to the ashes. Water is then added to the bones so as thoroughly to saturate them, after which they are turned over frequently in the course of a few hours. If a sufficient quantity of water has been added to the bones, it is not necessary to dilute the acid any further. If one part, by measure, of acid is to be used with three parts of water, it is better to use one-half of this water to saturate the bones, and to dilute the acid with the other half of the water. After the bones have been turned the acid is added gradually, the bones being constantly turned and mixed with the spade. In six or eight hours after the addition of the acid, the fine bone-dust, forming the second circle, is thoroughly mixed with the bulk. Next day the ashes forming the outer wall are thrown over the heap, which is then left undisturbed for a week. The heap is then opened out and thoroughly mixed with the ashes, and finally passed through a sieve. If not sufficiently dry for this last operation, a further quantity of ashes may be added to it.

Composition of Superphosphate of Lime.—It is extremely difficult to give the average composition of superphosphate of lime, which might serve as a standard of comparison for this substance, as Peruvian guano does for manures of that class. This arises from the difference in the materials, and in the mode of manufacture.

According to theory, if one hundred pounds of raw bones could be perfectly acted on by twenty-nine pounds of strong sulphuric acid, the composition of the resulting superphosphate would be in round numbers—

Moisture,	10	
Animal matter and fat,	27	
Sulphate of lime,	39	
Biphosphate of lime,	24	= to 35 parts of bone earth phosphate rendered soluble.
	100	

The animal matter, about twenty-one per cent., would furnish about one and a half pounds of ammonia. It is, however, practically impossible with these quantities to convert the bones as completely as stated above, into superphosphate.

Of one hundred and seventy-one samples analysed by Way, he found

		Per cent. of soluble phosphates.
11	samples containing	5
49	" " between	5 and 10
60	" " "	10 and 15
40	" " "	15 and 20
11	" " over	20

From these analyses he concludes, that a good superphosphate will contain between ten and twenty per cent. of soluble phosphate; that is to say, the biphosphate is calculated so as to represent neutral phosphate, which is thus represented as soluble. In round numbers, twenty-four parts of biphosphate are equivalent to thirty-five parts of bone-earth phosphate rendered soluble.

Anderson, Way, and the Editor, from numerous analyses, have adopted fifteen per cent. as the average amount of soluble and the same of insoluble phosphate in the above article as vended. With these data, the average composition of superphosphate in the market in 1856 was

Moisture,	10	
Animal matter,	27	
Biphosphate of lime,	10	= to 15 per cent. of soluble bone earth.
Insoluble phosphate of lime,	15	
Hydrated gypsum,	34	
Alkaline salts,	4	
	100	

Ammonia, about 1·5 per cent.

The money value of this superphosphate, calculated according to the plan adopted for guano, after leaving out the non-essentials, would be as follows:—

			Per ton.		
Soluble phosphate of lime,	15	×	£33	=	£495
Insoluble phosphate of lime,	15	×	7	=	105
Gypsum,	34	×	1	=	34
Alkaline salts,	4	×	1	=	4
Ammonia,	1·5	×	56	=	84
					£722

Price about seven pounds five shillings per ton.

According to the opinion of some agricultural chemists, the manufacture of superphosphate of lime will be imperfect so long as insoluble phosphate figures as one of its ingredients. Manufacturers now send superior articles into the market, and many samples of superphosphates are found in which no insoluble phosphates exist, and the proportion of the soluble phosphates is considerably above twenty per cent.

Analysis, Adulteration, et cetera, of Superphosphates.—The analysing of superphosphate of lime is substantially the same as for guano. The determination of phosphoric acid in the soluble phosphates may be rapidly and conveniently made in the following manner: A considerable quantity, say a quarter of an ounce is taken and mixed with about four ounces, by measure, of hot water, and allowed to settle, and the supernatant fluid poured through a filter. The residue is treated in the same way, two or three times, with a fresh portion of water. About a quarter portion of this fluid is taken for analysis, neutralized with ammonia, and again rendered acid by acetic acid; and after the addition of acetate of potassa or ammonia. the phosphoric acid is precipitated by the addition from an alkalimeter of a solution of sesquichloride of iron of known strength. After being rapidly filtered, and washed with hot water and dried, the increase in weight over the known quantity of sesquioxide of iron added, represents the phosphoric acid, 48 5 of which correspond to one hundred parts of bone-earth phosphate rendered soluble, and 71·5 to one hundred of biphosphate of lime.

Application of Bone Manure.—As a manure for grain crops, bones are not in repute. Their addition, however, is of use on those soils, such as peats, in which phosphates are deficient. It is almost exclusively in the light of a turnip manure that bones hold their high place in agriculture. The mode of using superphosphate of lime is either in solution or in compost. The former is the more effectual method, but it is attended with more expense and inconvenience; hence the latter is the plan generally adopted. It is applied in drills with the seed. The quantity employed should vary with the circumstances of the soil, and with the quality of the manure. About five hundredweight per acre is an average quantity.

The remaining special manures may be regarded as divided into the nitrogenous, or those employed for their nitrogen; and the mineral, or those taken for the bases they contain.

The nitrogenous manures of vegetal and animal nature, such as wool, horns, and the like, are slow in their action. They undergo decomposition very gradually in the soil, with the liberation of ammonia; hence they are but of little value when an immediate effect is required. Recourse must then be had to a salt of ammonia, or nitrate of potassa or soda.

When the various points discussed in the preceding pages are borne in mind, it cannot but excite surprise to see, on the one hand, the loss sustained by old and long-known manures from utter unacquaintance with their really valuable ingredients; and, on the other, to notice how many sources are at present neglected, from which fertilizing agents, either general or special, might be obtained. The dire necessity of augmenting the production of the soil in proportion to the increase of the population, has compelled practical agriculturists to call in the aid of science. The few years in which science and practice have been united have already effected the solution of many contradictory and crude opinions, based on blind empiricism, by showing wherein really consisted the value of manures, and the proper mode of treating them, so as to obtain their maximum fertilizing effects, and by directing attention, on well-grounded principles, to many hitherto-neglected sources of manures. The old struggle still continues between blind practice and the new views. The energy of the numerous scientific men who now devote their talents to agricultural chemistry leads, however, to the hope that, in a few years more, the laws which govern the proper tillage of the ground will be more thoroughly investigated and understood; agriculture will then take its stand as a more exact science than at present, and the cultivation of crops can then be entered upon as an art with as much certainty as any other manufacture.

Artificial Manures.—Twenty-five years ago, when the manufacture of spa and mineral waters began, they met with violent opposition from the members of the faculty, as being deprived of all the good qualities of the natural ones—as wanting, in a certain *conditio, sine qua non*—in a *spiritus rector*, or vital power, which alone gave them any medicinal qualities. Those times have passed now; chemistry has demonstrated to a certainty what the constituents of those various waters are, and under what forms and compounds they are united in them. It has succeeded in combining them exactly in the same proportions, and in rendering them not only equal to the natural ones, but *even more effective*. Physicians now connect certain effects on the human body with certain elements in the waters, and are enabled, by the light of science, to add more of this element, or more of that; nay, to apply, instead of the waters themselves, the one active element alone, as is, for instance, the case with iodine in indurations and struma. It is well known that at this moment there are extensive manufactories of mineral waters in England, at Berlin, at Dresden, at Vienna, *et cetera*. The mineral waters which are manufactured by the Messrs. Ellis at Ruthin, in North Wales, and by a few other firms, are in every respect equal, if not superior, to the natural ones. Now, the Editor believes that the same principle may be applied, partially at least, to the use of manufactured manures; and, in fact, this is proved by the success that has attended the application of several. To dwell at large upon all the artificial manures that are now manufactured in hundreds and thousands of tons annually, would occupy more space than is at the Editor's command; he will, therefore, only append the analyses of those which have come under his immediate notice, and which have been eagerly sought after by the agriculturist. The recipes may be improved, no doubt, still the manufacturers of artificial manures may profit by studying the various per centages of the different constituents in each. Three of the best have been selected out of the numerous samples that have been analysed by the Editor. No. 1 is a manure manufactured by Messrs. Knight and Company, Widnes, near Warrington, an inspection of whose works will prove interesting to the agriculturist. No. 2 is made by the British Patent Manure Company in Manchester; and No. 3 is produced at the Runcorn Bone Works. Most satisfactory results have been obtained wherever the composts have had a fair trial:—

	1.	2.	3.
Water,	24·00	12·07	20·00
Sulphate of ammonia,	10·84	15·97	14·85
Phosphate of lime and magnesia,	35·50	16·84	24·07
Biphosphate of lime,		10·11	6·81
Sulphate of lime,	9·16	5·40	7·20
Sulphate of magnesia,	—	6·72	—
Alkaline chlorides,	1·08	4·12	·54
Silicate of potassa,	—	5·47	—
Nitrogenous organic matter,	1·40	13·29	20·31
Insoluble matter, *et cetera*,	18·02	10·01	6·22
	100·00	100·00	100·00

In concluding this article, the Editor feels great pleasure in expressing his thanks to his talented friend, Dr. Blyth of the Queen's College, Cork, for much valuable matter that he has supplied during its compilation. The Editor could not have had a more competent contributor, for Professor Blyth was for many years the agricultural chemist at the college of Cirencester, where daily, under his inspection, were carried out experimental researches on the different kinds of manures.

MERCURY.—*Mercure*, French; *Quecksilber*, German; *Hydrargyrum*, Latin.—Mercury is a substance which has only of late been raised to the dignity of a metal, notwithstanding its being known long before the Christian era, and extensively experimented upon, more especially whilst the powerful idea of transmutation, and of the *elixir vitæ*, possessed the minds of the first chemical students—the alchemists. Its characteristics are very marked, and in one respect different from any other known metal, namely, its fluidity at all ordinary temperatures. It was this property, coupled with its silvery whiteness and metallic lustre, which determined its other popular name, quicksilver. Though it is not spoken of in the ancient scriptural writings, still Thomson in his *History of Chemistry*, states, that its discovery must have preceded the earliest historical records. It was common in the time of Moses; for, according to Dr. Herbert, the Egyptian magi employed it in their so called *enchantments*, when every man cast down his rod and it became a serpent. Aristotle relates, that Dædalus gave motion to a wooden Venus, by means of a current of mercury. Dioscorides describes a method for its reduction from cinnabar, or *minium*, as it was then designated, and which is remarkable as being the first record of a process that led to distillation. The metal in those times was employed in gilding, much in the same way as at present, and the minium or cinnabar had its application in painting and decoration. Pliny mentions that Callias, an Athenian, was acquainted with the preparation of the mercuric sulphide. The Greeks converted considerable quantities of the latter compound to this use, and were in the habit of drawing their supply from Spain, the mines of which were known and worked seven hundred years before the Christian era. In latter times the virtues of the sulphide as a medicine was established, and this, as well as the metal, was extensively administered by the professors of the healing art.

DIOSCORIDES, who cites some of the properties of the metal, had, it is evident, but an imperfect knowledge of it; for he states, that it could be retained in vessels of glass, tin, lead, or silver—an assertion which is now well known to be untrue, especially with regard to the metals that he named. **PLINY** also seems undecided as to its true nature, since evidently he thought that there was some radical difference between the mercury which was found in the virgin state and that obtained by the manufacture of the time. The former was known as quicksilver—*argentum-vivum*—and the latter as mercury—*hydrargyrum*. This doubt lurked in the minds of even the learned alchemists and philosophers till towards the close of the seventeenth century, when both kinds were submitted to numerous distillations—as in the case of **BOERHAAVE**, who distilled the same portion of mercury successively five hundred times, and the products were found to coincide in weight and all the then known properties. Still, at this period, owing to its fluidity especially, it was regarded as an imperfect or semi-metal, containing a principle regarded as pure vitrifiable earth—the silica of modern time. The fact of this terrestrial principle conferring solidity upon such bodies as contain it in abundance, being directly opposed to the fluid condition of mercury, induced **BECCHER**, an investigator of the first half of the seventeenth century, to admit the existence of another principle, a *mercurial earth*, which was supposed to possess weight and volatility to a very great degree. This chemist regarded quicksilver as a compound of three substances—namely, the vitrifiable, the inflammable or phlogistonic, and the mercurial. He was supported in his views by **STAHL** and other learned semi-alchemists, till by the introduction of a course of experimental research and deductions, the nature of bodies came to be regarded in a simpler but truer light, which overthrew the hypothetical obscurity that pervaded all chemistry up till that time.

The knowledge that it could be solidified, acquired by the academicians of Petersburg in 1759, was the first means to remove the notion of its semi-metallic nature, and inquiries to which the announcement of the fact gave rise in the hands of **PALLAS**, **HUTCHINS**, **BIEKER**, **BLAGDEN**, and several others, led the way to its recognition as a true metal, and elementary body.

PREPARATION.—Several methods are known for the production of mercury from its saline combinations, many of which are practised on the large scale, and will consequently be described when treating of its smelting, but as these do not yield a pure metal, reference will be here made only to the methods that are calculated to afford such a product.

The mercury of commerce, which usually is contaminated with variable portions of lead, tin, and bismuth, may be distilled with one-tenth of its weight of cinnabar; and provided the distillation be carefully effected, the foreign impurities will be found in the retort, in the form of sulphides, after the pure mercury has passed over into the receiver. A purer product is, however, obtained when carefully prepared cinnabar or corrosive sublimate—chloride of mercury—that has been cautiously sublimed, is distilled with one part of quicklime or iron filings. The principal part of the impurities is removed in the formation and sublimation of the sulphide or chloride taken, and the last traces are retained, with the sulphide of calcium, or iron, generated in the second part of the process. Sometimes agitation with concentrated nitric or sulphuric acids has the effect of rendering mercury much purer, but, in any case, can the product obtained by the process described be excelled. To ascertain its purity, it is only necessary to dissolve a portion in an excess of nitric acid, evaporate the solution, and heat the dry salt to redness; or fuse the metal with pure sulphur, and sublime the product in a glass mattrass; in either case nothing should remain if the metal be pure, but if a residue appear, the impurities are proportionate to its weight. Observation has led to the adoption of a simpler, but less reliable test than the above; it is this, that pure mercury when dropped upon a smooth, but slightly-inclined surface, breaks up into drops which retain the spherical form, but if contaminated with tin, lead, or such adulterants or impurities, the form of the globules will appear elongated, so as to present or leave *a tail*.

PROPERTIES.—Mercury is a metal that possesses the metallic lustre in a high degree, and exhibits a silvery whiteness. It is fluid at all temperatures between 39·5° Fahr., and its boiling point, which is variously estimated by different experimenters, as ranging between 654·8° **CHRICHTON**; and 680° **DULONG** and **PETIT**—**DALTON** estimating it at 660·2°; and **HEINRICH** at 672·8°. At *minus* 40° it solidifies, and while in this state permits of being beaten out under the hammer, welded, *et cetera*, like other metals. When the refrigeration is effected by means of solid carbonic acid and ether in a dish, and if the yet unsolidified portion be poured off, the metal adhering to the walls of the vessel will present well defined octahedral crystals. Its density varies with the degree of temperature more than any other metal, owing to the freedom with which it expands. **SCHULZE** found it in the solid state to be 14·391. **REGNAULT** estimated the gravity at — 40° to be 14·4, but if it could be compressed by hammering, the number would doubtless be higher. At 39·2° **KOPP** estimated its gravity at 13·594; **KUPFFER** at 13·588. and 13·535 at 78·8°; at the latter degree the number arrived at by **CAVENDISH** and **BRISSON** was 13·568; by **FAHRENHEIT** 13·757. **KARSTEN** determined its density at the ordinary temperature to be 13·559. Various researches show that this metal evaporates at common temperatures, as well in contact with air as *in vacuo*. This may be proved by suspending gold leaf in a flask containing some of the metal, when, after a few weeks, the lower portion of the leaf will appear amalgamated. **KARSTEN** asserts that at 32° mercury gives off as much vapor as to develop the image on a daguerreotype plate held over it at a convenient distance. **BRAME** affirms that sulphur in a finely-divided condition, as when precipitated from a state of vapor, is much more delicate than gold leaf. By its aid he found that at 53·6°, the tension of the vapor rises to the height of three feet, and even higher than this; but, in the latter case, the delicacy of the known tests is inadequate for its detection. This investigator is also of opinion that in air and vapor of sulphur, the vapor of mercury diffuses itself according to the law which governs other gases.

The specific gravity of the vapor of mercury was found by DUMAS to be 6·976, and by MITSCHERLICH 7·03—the latter number being that arrived at by theory. The property of expansion which mercury possesses, and the long range of temperature through which it exhibits this property with remarkable regularity, render it peculiarly adapted to the wants of the philosopher for determining the sensible heat of bodies. Repeated experiments have shown, that between 32° and 212°, the increase of bulk which it acquires, by the acquisition of equal increments of heat, is extremely regular, and corresponds to 0·00011 of its bulk at 32°, according to the experiments of DALTON. Between 38° below zero—the lowest degree of temperature that can be safely estimated by the mercurial thermometer—and + 32°, the freezing point of water, the gradation is not so regular, although the difference is so trifling as to be disregarded in most applications; but between 212° and 662°, it has been found to pass from the regular expansion observed between the limits of the freezing and boiling points of water, and to increase in this respect as the heat becomes more elevated. The annexed table exhibits the ratio of expansion of mercury between 32° and 212°, as determined by the investigators mentioned :—

·0200	Dalton.
·01887	Cavendish.
·01848	Lavoisier and Laplace.
·01818	Hallstrom.
·01801	Shuchburgh.
·01800	Dulong and Petit.
·01781	Deluc.
·01695	Roy.
·018153	Militzer and Regnault.

The following numbers, arrived at by DULONG and PETIT, show the variable and increased expansion of mercury above air by equal increments of heat :—

COMPARATIVE EXPANSION OF AIR AND MERCURY BY THE SAME INCREMENTS OF HEAT.

Dulong and Petit.		Rudberg.	
Air.	Mercury.	Air.	Mercury.
0·	0·	— 35·96	— 36·
100·	100·0	0·	0·
150·	151·3	+ 50·04	+ 50·
200·	204·6	100·	100·
250·	255·1	198·81	200.
300·	314·15	294·73	300·
350·	360·00	—	—

Mercury is not acted upon when exposed to air, oxygen, nitrogen, nitrous or nitric oxide, or carbonic acid gases. On the contrary, if shaken with water, ether, oil of turpentine, or fatty unctuous matters, it loses its metallic appearance, and is converted into a grey *æthiops per se*, in which the metal is not altered but *deadened*—that is, reduced to minute and isolated globules by the interposed stratum of the compounded matter. Ordinary mercurial ointments retain the metal in this state, but so finely divided as to render its detection by the unaided sight impossible. When pure it is tasteless and inodorous, although a peculiar odor has been observed from it when rubbed between the fingers. Poured upon dry bodies, it does not wet them like other liquids, but flows off in drops, except in the case of the metals with which it forms amalgams. On this account it is designated, sometimes, in old writings, *aqua non madefaciens manus*—water that does not wet the hands. Kept at a temperature approaching ebullition in contact with air, it suffers oxidation slowly. Water is not decomposed by it. The nitrous, nitric, iodic, chloric acids, *et cetera*, easily oxidise it without the aid of heat; sulphuric acid, when diluted, has no action upon the metal, even when aided by heat, but concentrated acid, at a high temperature, readily converts it into a protosulphate, sulphurous acid being eliminated. With selenium, sulphur, phosphorus, chlorine, bromine, and iodine, it unites with facility, giving rise to the haloid mercurial compounds of those radicals. It quickly combines with the noble metals—also with tin, lead, bismuth, zinc, and most of the soft metals, giving rise to amalgams which often possess particular interest. This is the case, more especially in a manufacturing sense, with the amalgams it constitutes with gold, silver, platinum, as they are available in the smelting or abstraction of these metals from the gangue in which they may be distributed. Indeed, a chief portion of the mercury annually extracted is devoted to this special application, so that a distinct relation between the yearly production of gold and mercury may be traced. Besides this application it has many others, such as gilding, plating, and the like. Many of its compounds are valuable in other branches of art, such as medicine, painting, *et cetera*, but more particularly in the former, where its administration is very varied and frequent. The metal is likewise very advantageous to the anatomist, who employs it as an injection, either alone or in the form of vermillion suspended in size. There are many other instances of its application, but not being very general, they will not be further dwelt upon.

Atomic Weight.—Before proceeding to notice the ores of mercury and the processes by which the metal is obtained from them, it may be mentioned that much difference of opinion has existed respecting the atomic weight of this element. The mercurial oxides are two in number—the *grey* and the *red;* and it is from the different view chemists have taken of the constitution of these bodies that 100 and 200, or a near approximation, have been respectively proposed as the equivalent of mercury. The composition of these bodies, denominated mercurious and mercuric oxides, is thus centesimally expressed :—

	Grey Oxide,	Red Oxide.
Mercury,	96·15	92·59
Oxygen,	3·85	7·41
	100·00	100·00

Now, if the *grey* be assumed to be the *protoxide*, then the value of an equivalent of mercury capable of saturating a full equivalent of oxygen, which is represented by 8, will be 199.8, or nearly 200; whilst, on the other hand, assuming this oxide to be the suboxide, and, halving that number, it will be represented by two equivalents of metal, and one of oxygen. Taking the equivalent of the metal, then, at 100, the atomic constitution of these oxides is thus represented :—

	Grey oxide.		Red oxide.
2 Eqs. Mercury,	200	1 Eq. Mercury,	100
1 Eq. Oxygen,	8	1 Eq. Oxygen,	8
1 Eq. Grey Suboxide,	208	1 Eq. Red Protoxide,	108

The chemical symbol of the metal is taken from its Latin name, and is written Hg.

Berzelius, Erdmann, Marchand, Gmelin, Regnault, Thomson, Graham, and many other chemists, have adopted 100 or something near it as the true atomic weight, and the preference is further justified by the fact, that though both oxides are salifiable, yet the grey is very unstable, and unlike a true protoxide in its characters, whilst the red is eminently persistent and basic; indeed, according to Brande, it almost approaches to alkalinity. Besides, the evidence adduced from the connection of the atomic heat of the metal with its atomic weight is decidedly favorable to that number which expresses the grey as a *sub*, and the red as a *prot*oxide. The experiments of Stranberg, published in the Memoirs of the Academy of Stockholm for 1845, go to prove that the atomic weight of mercury cannot be less than 99·90.

Ores of Mercury.—The minerals into the composition of which mercury enters, are by no means numerous, and few of them are important. The metal itself occurs native in the form of fluid globules scattered through its gangue. The quicksilver mines of Almaden in Spain, of Idria in Carniola, of Wölfstein and Morsfield in the Palatinate of Roscna in Hungary, and Sala in Sweden, supply specimens of the virgin metal, which was said at one time to fetch a higher price than that obtained by reduction. In some places native mercury is so plentifully dispersed through its ores, that when an opening is made it escapes, and trickling out, collects in considerable quantities at the bottoms of the levels.

A native amalgam of silver, amorphous and crystallised, is also met with. Not unfrequently this mineral occurs in the form of flattened plates. A specimen, said to be from Peru, the specific gravity of which Dr. Dalzell determined, did not exceed 13·995, but usually it is 14·119. From the average of the analyses of three specimens examined some years ago by the same chemist, along with the analysis of other specimens by Klaproth and Cordier, it consists centesimally of—

	Dalzell.	Klaproth.	Cordier.
Mercury,	56·1	64·	72·5
Silver,	43·9	36·	27·5
	100·0	100·	100·0

That the composition of this mineral should vary considerably does not seem surprising, since it has been proved that mercury evaporates from mercurial ointment and amalgams. *Arquirite*, an argentiferous amalgam of great value, is found in considerable quantity in the province of Coquimbo in Chili. It contains 13·5 parts of mercury, and as much as 86·5 per cent. of silver. Indeed, this is one of the chief ores of silver in the rich mines of Arguiros. An amalgam of gold, analysed by Schneider, and which occurred along with platinum ore from Columbia, contained mercury 57·40, gold 38·39, and silver 5·0. Native amalgams of lead, containing selenium, have been analysed by Rosé.

Horn quicksilver—subchloride of mercury, or native calomel—is found associated with the other ores of quicksilver at Idria, at Deux-Ponts, in Spain, and elsewhere. It is a yellowish or ash-grey mineral, sectile, and subtranslucent. Sometimes it occurs as a crust, or forms granular concretions. At other times it crystallizes in four-sided prisms. Its specific gravity is 6·482, whilst that of the powdered calomel of the shops is 7·14, and that of the crystallized factitious subchloride is 7·2.

Iodides, bromides, and selenides of mercury also occur, but rarely. The iodide has been met with in Mexico, associated with the selenide. A specimen of the bromide Dr. Dalzell found to contain, besides bromine, traces of iodine, selenium, and sulphur. Rosé has described the selenide as composed of selenium 6·49, sulphur 10·30, and mercury 81·33.

The principal ore of mercury is the sulphide—the *zinnober* of the Germans and *minium* of Pliny. The color of native cinnabar varies from cochineal red to brownish-red and leaden grey. The streak is scarlet, and the lustre usually adamantine. The density of this mineral is 8·098, and when pure it contains 86·29 parts of mercury with 13·71 of sulphur. Specimens of the purest ore have, occasionally, all the richness of hue which the best vermilion presents.

The following table shows the composition of cinnabar from various quarters of the world, the amount of the constituents being centesimally expressed:—

	Mercury	Sulphur.	Bitumous matters	Gangue.	Water.	Carbon.	Silica.	Alumina.	Iron.	Copper.	Lime.	Magnesia.	Total.	
Japan,	84·50	14·75	—	—	—	—	—	—	—	—	—	—	99·25	Klaproth.
,,	79·30	14·50	—	—	—	—		5·67		—	0·63	—	100·10	Dalzell.
Idria,	51·80	8·20	6·80	32·0	3·20	—	—	—	—	—	—	—	102·00	Lebererz.
Idrian Swaore,	81·80	13·75	—	—	0·73	2·30	0·65	0·55	0·20	—	—	—	99·00	Klaproth.
Neumarktel,	85·00	14·25	—	—	—	—	—	—	—	—	—	—	99·25	,,
Wolfstein,	18·00	—	—	—	—	—	—	—	73·31	—	—	—	91·31	Bealey.
Almaden,	37·84	16·22	—	—	—	—	35·12		—	—	—	—	89·18	,,
,,	37·75	16·22	—	—	—	—	35·12		—	—	—	—	—	,,
,,	36·94	15·97	—	—	2·58	—	42·79		—	traces.	—	—	98·28	Dalzell.
,,	41·79	16·72	—	—	—	—	41·49		—	—	—	—	100·00	,,
California,	69·36	11·38	—	—	—	—	14·30	0·61	1·23	—	1·40	0·49	98·77	Bealey.
,,	70·13	11·21	—	—	—	—	14.52	0·61	1·23	—	1·40	0·49	99·59	,,
,,	70·23	11·21	—	—	—	—	14·52	0·61	1.23	—	1·40	0·49	99.59	,,
,,	72·00	12·80	—	—	1.20	—	—	—	14.0	—	—	—	100·00	Dalzell.

Geologically, the ores of mercury occur amongst stratified deposits. The volatility of the metal may account for its not being met with in any large quantity in crystalline or igneous rocks. Thus, it is found most abundantly in the independent coal formation, and in beds lying between primitive argillaceous schistus and chlorite slate, associated with quartz, calcareous spar, spathic iron, and copper pyrites. In the famous quicksilver mines of Almaden in the province of La Mancha, a few miles from the frontier of Estremadura, which have been worked for many centuries, the veins traverse micaceous transition schists and sandstone grit, intersected here and there by granitic and porphyritic eruptions. A portion of the Almaden ore is extremely rich; but the larger proportion is so intermixed with quartzose and argillaceous gangues, that the yield is not over ten per cent. of metal. At Quença in New Granada, Durasno in Mexico, and in some of the Peruvian mines, the mercurial ore occurs in the red sandstone above the coal; whilst at Deux-Ponts, at San Juan de la Chica in Peru, and in some other localities, it is placed in the subordinate porphyry. The mines of Idria are worked in a friable compound of dark carbonate of lime, and argillaceous schist. These mines were discovered in 1497, before which time the country was inhabited only by a few artificers in wood. Tradition thus records their discovery:—A cooper having one evening placed a new butt under a neighboring spring to try if it would hold water, when he returned the next morning to take it away, found it so heavy that he could with difficulty move it. Being an ignorant man he at first supposed his vessel was bewitched; but at length perceiving that it contained a heavy and brilliant liquid metal, he carried away some of it, and showed it to an apothecary in Laubach, who, being better informed than the peasant, and more cunning, kept the mercury, sent the man away with a small gratuity, and directed him to bring him all he could obtain. This the cooper did for a considerable time, till the affair became known, when a society was formed, and a further search for quicksilver instituted. The mines remained in possession of this society till the Archduke Charles of Austria, perceiving their importance, purchased the properties, and took the mines of Idria also under his control.

The subterranean passages of these mines are extensive; but owing to the loose and friable nature of the ground, large excavations are impossible. Their greatest perpendicular depth, taken from the entrance of the shaft, is about eight hundred feet; but as the galleries advance horizontally under a high mountain, the depth would be much greater if measured from the surface of the hill. The mine was formerly entered either by descending the shaft in a bucket, or by zig-zag ladders. By the first route the visitor was subjected to the inconvenience and danger of being stopped by some projection; or the bucket might even strike against the side and be upset. Nor was the ladder descent more safe and agreeable; for the steps being wet, slippery, and narrow, the utmost caution was requisite to prevent falling. Now, however, the entrance is through a large iron gate, by a horizontal passage to a descending flight of seven hundred and fifty-seven steps, cut in the limestone rock, and provided with a hand-rail. At the bottom of these steps there is a small chapel in which the miners perform their devotions, and from which a labyrinth of passages opens out. In some of the galleries the heat is so intense as to be almost insupportable. The noxious inhalations of the metal speedily become so offensive that the visitor is glad to make his escape. The ascent is usually performed by a perpendicular shaft at a considerable distance from the spot where he entered, and through which he is raised in a cage or bucket.

In 1803 a fire broke out in the workings, and was with great difficulty extinguished. Fumes of mercury filled the air; and throughout the neighborhood, nine hundred people were affected with the most urgent symptoms of mercurial poisoning.

These mines continue to be worked by the Austrian government, which restricts their annual yield to one hundred and fifty tons. URE states, that but for this avaricious enactment for keeping up the price of mercury, six hundred tons would easily be produced yearly. Some of the ore yields fifty to sixty per cent. of metal. The richest qualities are termed *stahlerz;* and the poorer, bituminous sulphide, averaging only ten per cent., are called *zeigelerz.*

Besides the quicksilver works, there is a manufactory of cinnabar, which annually produces about ninety tons. Benevolent institutions have also been established for the treatment of those miners whose health has suffered from the action of the mercurial fumes.

The mercury mines of the Palatinate are not equal in richness and importance to those of Idria and Almaden. The workings at Drey-Kœnigszug, at Potzberg near Kussel, give an annual yield of about thirty tons. —PHILLIPS. The ore there is sandstone, intimately mixed with sulphide; and the depth to which the explorations have been carried exceeds six hundred and sixty feet. The aggregate yearly average of several still smaller mines in Hungary, Bohemia, and other parts of Germany, does not, according to URE, exceed thirty to forty tons. The quicksilver mines of Huancavalica in Peru, the products of which are employed in the treatment of the gold and silver ores which abound in that neighborhood, have been worked since 1570. Up to 1800 their produce was fifty-three thousand seven hundred tons of quicksilver.

Several accounts of the Californian quicksilver mines of New Almaden have been published. The following early notice was communicated to Silliman's *Journal* by the REV. C. S. LYMAN, in a letter dated—Pueblo de San José, March 24, 1848—not quite two years before the supply from this quarter reduced the price of mercury:—The mine of New Almaden is situated a few miles from the coast, about midway from San Francisco and Monterey, and in one of the ridges of Sierra Azul mountain. The mouth of the mine is a few yards down from the summit of the highest hill that has yet been found to contain quicksilver, and is about twelve hundred feet above the neighboring plain, and not much more above the ocean. This hill extends longitudinally in a north-west direction, decreasing in height; and in various parts of it, for several miles, traces of the ore have been found, and some openings have been made which promise to be valuable. This range of hills consists of a variety of rocks—the prevailing one is a greenish talcose rock, which seems to embrace the bed of ore at the New Almaden mine, both above and below. The ore is interspersed through a yellow ochreous matrix, which forms a bed forty-two feet in thickness, dipping north-westerly at an angle of about 45°. The richest ore is at present found in the upper part of the bed; the poorest ores being taken from the lowest portion.

This mine, known to the aborigines from time immemorial as *a cave of red earth* from which they obtained paint for their bodies, was first discovered to contain quicksilver about four years since, during experiments made by some Mexicans to smelt the ore for the purpose of obtaining *gold*, which they supposed it to contain. About two years ago it fell into the hands of Barrow, Forbes, and Company, who commenced working it. The great trouble was to obtain suitable apparatus for extracting the metal. At length four potassa kettles were found, which were set in a furnace of adobes, with condensers of mason work immediately adjacent,—a wretched apparatus indeed for managing a thing so subtle as mercurial vapor. The daily mode of working was to fill these pots in the morning with one thousand six hundred pounds—four hundred to each pot—of the ores of average quality, broken in lumps of the size of apples, put on the covers, and lute them with a layer of *sand*. The fires were then kept up till near night, when the furnaces were allowed to cool gradually. The next morning the condensers were opened, and the metal dipped up, which usually amounted to from two to three hundred pounds from the four pots. This was a much less per centage than the usual assay indicated, and it was obvious a large portion of the metal was lost. The upper part of the pots and condensers was found to be generally covered with a crust of sulphide of mercury. Mr. Forbes wished to devise some way of extracting the metal without mixing lime with the ore in roasting, but was unsuccessful. At length a kiln of lime, which occurs in the immediate vicinity was burned, and I am informed that the ores yield with this a vastly greater per centage of metal. In the last three weeks, about ten thousand pounds of metal have been extracted with the same apparatus, being a yield of over fifty per cent. The mine is probably giving a net profit of one hundred thousand dollars a year, with its present crude apparatus. With suitable furnaces, and iron cylinders or retorts, the mine would easily yield a million and upwards.—*Lyman*.

New Almaden, writes Mr. Russel Bartlett in 1853—that is five years later—now consists exclusively of the buildings belonging to the Company which owns the quicksilver mine. It embraces furnaces, storehouses, dwelling-houses for the officers and laborers, offices, mechanics' shops, *et cetera*. Many of them are of wood, but a large and fine range of substantial brick buildings is now in process of erection to take the place of the wooden ones; six furnaces are now in operation reducing the ore, all of which seem to be alike and of the most simple construction; the furnaces are kept going night and day, and the metal is collected in tanks, the largest of which holds twenty tons. The Californian metal comes into the market in wrought iron bottles, screw stoppered, and holding seventy-five pounds each. The bottle itself weighs about twenty-five pounds. A land carriage of about twenty miles, performed in the ore carts, brings them to the point for shipment. The New Almaden produce in 1853, equalled one hundred thousand bottles per month, or one million per annum. During the same year the following exports from San Francisco took place, the whole of the metal being the produce of the New Almaden mine.

		Pounds
Shipped for	Hong Kong	423.150
	Shanghae,	60.900
	Canton,	27,450
	Whampoa,	22,500
	Calcutta,	3,750
	Mazatlan,	210.825
	Mazatlan and San Blas,	19,125
	San Blas,	145,652
	Callao,	135,000
	Valparaiso,	148.275
	New York,	138.375
	Philadelphia,	75,000

Further particulars of this interesting mine were published in 1856, in the *American Journal of Pharmacy*. The present entrance to the workings is by a horizontal shaft and railway twelve hundred feet long. The large masses of rich and compact ore, some of which weigh as much as twenty pounds, are separated from the small fragments which are mixed up with yellowish earth and clay. The latter are pounded, kneaded up with water, and dried in the sun; thus baked, they are called *adóbés*. The smelting furnaces, of which with their condensing chambers there are fourteen, are situated a mile and a quarter from the entrance to the mine. Each range consists of a fire chamber three feet by five, placed at the end of a series of eight or ten chambers, seven feet long, four wide, and five high. The range is built of brick, plastered inside, and protected against expansion by heat by iron rods passing from wall to wall, and secured with screws and nuts. The tops are of boiler plate, luted with salt and ashes. The first or fire chamber is separated from the second or ore chamber by a network partition of fire-brick. The third chamber communicates with the ore chamber by a square opening at the right upper corner, and this first condensing chamber with the second, by a similar opening at the left lower corner, and so on; the top openings being on the right, and the lower openings on the left, alternately. From the last condensing chamber the vapors pass into a wooden hose, in which there is a continuous shower of cold water, while any uncondensed matters pass into the open air through tall wooden flues. The floors of the condensers are guttered, and by these the mercury flows into an open conduit, from the end of which it pours over a brush into the iron bottles already described.

The lumps of cinnabar and the adóbés are piled like bricks in the second chamber, a wood fire is lighted in the furnace, and the flame plays through the brick network on the ore. Each ore chamber, when fully charged, contains ten thousand pounds of cinnabar, to exhaust which requires sixty hours. At this period, lime appears not to be used in the reduction of the ore. Ruschenberger conceives that the addition of this substance would increase the yield, but not, he adds, sufficiently to pay the cost of the earth. This is singular, as Lyman speaks of lime occurring in the immediate vicinity.

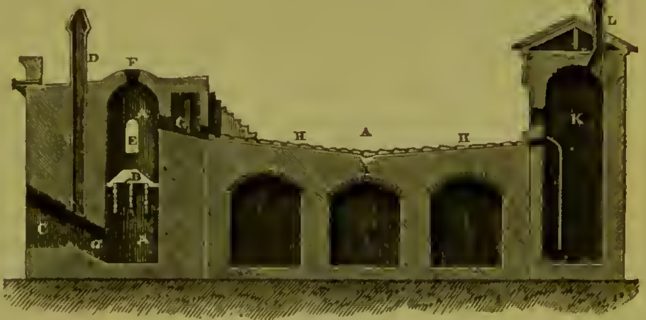
Assay of Mercurial Ores.—It may be well to state here the means by which ores of mercury may be assayed, more with the view of showing how much metal should be obtained on the large scale, rather than giving a precise method of analysis. The methods followed are distillation of the product, whether it be oxide, chloride, sulphide, selenide, or iodide, with caustic lime; if only a sulphide be present, simply subliming it; but this offers no advantages, since a higher heat is required, and there is always a liability of a portion being reduced, the metal passing over with the cinnabar, and exposing the results to error.

When lime is employed, from fifteen to twenty-five parts may be taken, according to the richness of the assay. This is intimately blended in a mortar with the finely ground ore, together with a tenth of the weight of the ore operated upon, of fine charcoal, and the whole introduced into an earthen or hard glass retort, with a long neck, and surrounded with cloths, on which a stream of water may be kept flowing for the purpose of condensing the vapors. The beak of the retort should likewise be inserted in a flask kept cool by wet cloths. The distillation may be carried on over a gas flame; or better, by means of a small charcoal fire and sandbath. All the mercury is transported into the neck of the retort in the state of vapor, where it condenses, and trickles into the receiver. When no more vapors arise, and the materials are carried to dull redness, the fire is removed, and any globules which may remain in the neck of the retort, made to flow over into the receiver by tapping it gently, or introducing a small brush; and after the whole has been collected, the product is weighed. In this way the yield of mercury is ascertained with a degree of accuracy which will be dependent upon the carefulness of the operator. The sulphur, or other mineralizing element of the ore, will remain united to the lime, or else form gaseous products with the carbon, and be retained or evolved according to their nature. Iron scales or carbonate of soda may be employed with equal effect; only, in case of iron being the agent, it should be finely divided and used in excess, to insure that none of the mercurial body may escape decomposition. When the experiments are carefully managed, the result in either case is very exact. Instead of using charcoal, hydrogen gas may be passed over the assay during the sublimation; but this is inconvenient, excepting where the resources of a well-regulated laboratory are available; and, besides, it does not make the results more correct in the hands of a careful assayer.

Reduction of Mercurial Ores on the large scale.—There is, with a few exceptions, very little diversity in the manner in which the smelting of mercurial ores is carried on. It is strange, however, that in the case of the largest and most important *lode* in the world, that of Almaden, the comparatively rude and inefficient method of working invented by Juan Alonsa Bustamente more than two hundred years ago, should still be followed in all its details; a method which, however remarkable and advantageous it might appear at that period, is now acknowledged to be much more laborious and incomplete than several others which are in practice at other mines of this kind. The defect of the system does not only directly affect the quantity of mercury extracted, and which, according to the testimony of M. Le Play, is far below the per centage contained in the ore, but, likewise, the workpeople in, and inhabitants of, the districts adjoining the seat of operations, in consequence of the baneful effects of the escaping mercurial vapors on the system. Le Play speaks upon this subject thus:—*Le mercure a sur la santé des ouvriers la plus funeste influence, et l'on ne peut se défendre d'un sentiment pénible en voyant l'impressement avec lequel des jeunes gens, pleins de force et de santé, se disputent la faveur d'aller chercher, dans les mines, des maladies cruelles, et souvent une mort prématurée.* Jussieu, on the contrary, states, that the vapors which escape from the chambers of condensation at those works, have no pernicious effect either upon the inhabitants or vegetation in their neighborhood; still, from the consideration of the process, and the imperfections evident in it, coupled with the known noxiousness of mercurial fumes, every attentive observer would be led to conclude that life and vegetation must suffer to a great extent both in and around the factory.

Figs. 356 and 357 represent a section and plan of the kind of apparatus employed, which is known as the *butyrone* or *aludel* furnace. It consists of a circular or polygonal chamber, A A, about four feet in diameter, and divided into two compartments by a perforated brick arch, B, about nine feet from the top. The heat is obtained from brushwood introduced at the aperture, C, into the fireplace, *a*, and the smoke is carried off in part by the chimney, D. A door, E, in the side of the cylinder, and an aperture, F, at the top, are used to introduce the charge of ore, the volatile products of which escape into the condensing media by a system of openings, G, and which communicate with files of condensers of earthenware, called *aludels*, H, connected one with another, as represented in Fig. 358. These are laid on two planes of brickwork, inclining to

Fig. 356.



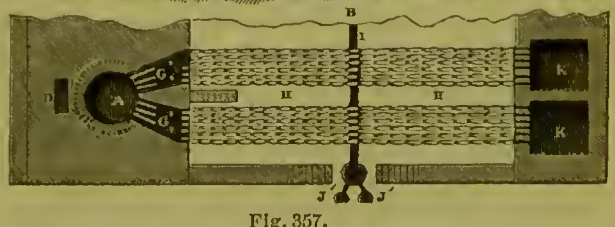
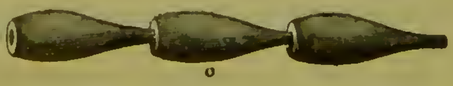


Fig. 357.

Fig. 358.



one another, supported on arches, as represented in Fig. 356. Where the two planes meet is a channel or gutter, I, leading to a conduit, I, in the brickwork, and thence by wooden pipes at the bottom to the receiving basins, J J, partly filled with water, and fixed in the floor of the smelting room. During the passage of the distilled vapors through the several files of aludels, the metal which condenses flows for the most part into the aludel which crosses the channel, I, and issues into the latter by a hole in its under part; the uncondensed products pass into the upper part of a condensing chamber, K, and are conducted towards the bottom by a screen, where a cistern of cold water receives the metal. Such portions as diffuse themselves in the chambers are deposited on the walls, in form of soot, and are from time to time brushed off and collected at the bottom. Sulphurous and other gases pass off by the chimney, L, but sometimes a second chamber is above the arch of the first, in which a further quantity of the metal is retained. Whatever is collected in this way is filtered, in order to purify it from other matters, and the dross is worked up with loam and fine or powder ore into bricks, and subsequently distilled over again. The charge of ore for this furnace averages from two hundred and twenty to two hundred and seventy hundredweight, and is divided into three varieties, each of which occupies particular places in the furnace. The larger pieces of the sandstone rock, slightly impregnated with cinnabar, and called *soleras*, are placed on the arch immediately above the fire. Being too poor to be worked by themselves, and requiring too much labour for preliminary dressing, it is worked off in this part of the furnace. Above the *soleras*, about twenty-two hundreds of rich mineral are laid on, then some poor ore in small fragments, and the remaining space is filled with the dross from the aludels and condensing chambers, some fine ore previously worked up with some clay and moulded into bricks. The door in the side, and also the aperture in the top, are then secured by the doors, and covers, and luting. After this, the adapters are arranged in proper order on the inclined planes, and the joinings secured by clay luting. The number of these vessels being so large, a good deal of time and labor is required for this work. There are six files in each bench, and forty-four vessels in each file, making, for the entire furnace, about five hundred and twenty-eight. From the aperture of the furnace to the condensing-chamber, the length is about sixty-five feet, so that each aludel is more than eighteen inches long. All things being ready, the fire is lighted and kept in active ignition by the supply of fresh brushwood. An abundant flame is thus produced, which passes up through the apertures in the arch of the furnace, and heats, first the *soleras*, and subsequently the remaining contents, and drives the whole of the metal into the aludels, volatilizing it with the sulphur in the form of sulphurous acid with a little sulphuric acid. According as the aludels become heated by the vapors, they begin to act more effectually the part of a series of chimneys, and so draw off the products more freely. The fire continues successively for twelve days to work off the charge, after which time it is permitted to die out; and three days further are allowed to cool the earthen adapters before they are detached, and the portion of mercury in them collected. This work also consumes a good deal of labor, as each receiver, after being detached, is to be brought to the channel midway to be emptied. Any metal shed in the carriage, runs along the incline, but is not lost; it becomes soiled, however, so that it is necessary to submit the whole to a purifying process. That adopted is very simple, merely pouring the metal on the floor of the room destined for the work, which being slightly inclined towards one end, the metal flows down clean and bright into a receiver, and leaves the dross and soot behind it adhering to the floor. A good deal of metal remains in the residue; hence it is carefully collected and worked up in the next charge. Each charge affords from twenty-five hundred to three thousand pounds of mercury; sometimes, when the ore is a richer kind, as much as six thousand pounds are obtained; but the manager tries to average the ore, so that the yield may be about the first-mentioned quantity. If the charge be enriched by using more of the purer ore, the loss in mercury is considerably greater than if only an average kind be worked; besides, the trouble arising from the cracking of the lutes securing the connection of the aludels, and their renovation, is multiplied. This was particularly remarked in 1787, when an innovation was made in the ordinary course of working, by employing a larger quantity of rich ore than that already mentioned. Fully half the metal in the surplus was lost, owing to the draught of the aludels being inadequate to carry it off, and the injury to the health of the smelters from breathing so much mercurial vapors was very serious. Besides the mercury, another substance is found to encrust the earthen cones, which PROUST found to contain—

	Centesimally.
Finely-divided mercury,	66·0
Subchloride of mercury,	18·0
Cinnabar,	1·0
Sulphate of ammonia,	3·5
Sulphate of lime,	1·0
Free sulphuric acid,	2·5
Carbon, or soot,	5·0
Water,	2·5
Loss,	0·5
	100·0

The same chemist estimates the extent of its formation at about forty pounds per charge, or in its content of metal equal to 1·500 of the weight of the rich mineral wrought, and attributes the presence of the subchloride to its being contained in the ore, and volatilized as such. Doubtless portions of this compound do exist in it, but it is likely also that a chloride is produced by a process of double decomposition that takes place between portions of the cinnabar and the alkaline chlorides in the particles of ash which are drawn up into the furnace by the draught; or a sulphate of mercury may be formed during the roasting of the ore or in the aludels, and this, in contact with the chlorides already mentioned, may produce the effect; or the chlorides meeting the continually-forming sulphuric acid may be decomposed, setting free hydrochloric acid, which, passing over the sulphate of mercury condensed in the aludels, gives rise to the calomel and free sulphuric acid. This loss is now, in part, avoided by mixing some quicklime with the *schlich* and clay in making the bricks, which occupy the upper space near the dome of the furnace. Cast-iron cylinders, bent, and surrounded with water, have been tried at Almaden, as a substitute for the aludels, but their use has been abandoned, in consequence of their being rapidly corroded by the free acid, although the mercury was found to condense very well in them. PROUST likewise analyzed the incrustation on these condensing pipes, and found—

	Centesimally.
Finely-divided mercury,	44·0
Sulphate of protoxide of iron	23·5
Sulphate of alumina and sulphate of potassa—alum,	14·5
Subchloride of mercury,	3·3
Sulphide of mercury,	6·3
Carbon,	4·8
Sulphate of lime,	0·9
Loss,	2·7
	100·0

The alum arose from the action of the sulphuric acid on the clay pipes which connected the iron condensers with the outlets of the furnace, and the potassa was supplied from the ashes of the fuel.

A portion of the Almaden mines, probably that now called Little Almaden, was worked by the Romans. PLINY speaks of *Sisapo, a territory of Bœtica, the mine of minium there forming a part of the revenues of the Roman people. Indeed*, adds the same historian, *there is nothing guarded with a more constant circumspection; for it is not allowable to reduce and refine the ore upon the spot, it being brought to Rome in a crude state, and under seal, to the amount of about two thousand pounds per annum.* The modern town, which contains about seven thousand inhabitants, is built over the principal mine, the entrance to which is close to the houses, and the ascent and descent of the miners effected by ladders. Not long ago, and possibly even now, the water was pumped from the mine by a WATT engine, made about the year 1790! The produce of the workings is drawn to the surface by mules, up a wide and well-constructed stone shaft. Convict labour was formerly employed by the Spanish government, but now free workmen, to the number of about five thousand, have been substituted, who work almost naked, and from Spain receive a high rate of wages. Their health, however, always suffers; but, as the workings are only carried on during winter, a release from confinement, with fresh air during the summer, usually restores them to health, and permits of their return to labor on the opening of the mines.

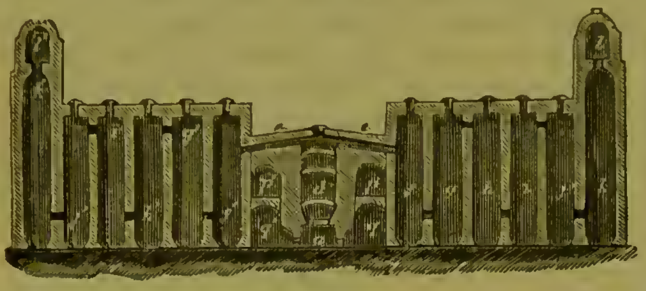
The produce of the Almaden mines, which is sent to Cadiz and Seville for exportation, is packed in cylindrical cast-iron bottles, which are closed with a screw stopper. Each bottle contains three Spanish arobas, making seventy English pounds net per bottle. But the weight charged by the importers is on an average only sixty-nine to seventy pounds, arising from the tret of four pounds per every one hundred and four pounds; and one pound draft being allowed; and the tare being fixed at eight pounds, whilst the real tare averages sixteen to seventeen pounds.—*Pereira.* In the sixteenth century these mines were rented by the brothers MARK and CHRISTOPHER FUGGER, the rich capitalists of Augsburg, under a contract for the payment of four thousand five hundred quintals of mercury yearly to the government. Unable to fulfil their agreement, they relinquished them in 1635. Ten years later, the Spanish government undertook their management. In 1831 N. M. ROTHSCHILD and SONS obtained from the Spanish government the contract for all the mercury they produced. With this monopoly the price, which in 1831 was one shilling and ten pence per pound, rose in 1849 to four shillings, whilst the cost of mercurial salts rose in the same proportion. Before 1850, however, Californian mercury appeared in the market, when the price of the metal per pound fell in the course of four years to two shillings and a penny.

Method of Reduction at Idria.—This famous mine was discovered so far back as 1497, but the working of the ore was very irregularly prosecuted for nearly a century afterwards, and even then there was no fixed establishment, but the ore and utensils necessary were carried about in the forests to where the charcoal-burner had chosen the site for his *meiler*, in order to make the heat of the burning wood available for the reduction of the ore. A number of earthen pots, with narrow necks, were filled with the ore, mixed sometimes with lime; the mouth was then stopped with a clay plug, so as to retain the charge, but allow the fluid metal to flow out into a wide-mouthed vessel, into which the charged one was inverted. As many of these as would fit in the base of the charcoal heap were arranged as described, and the clay or soil raised about the subjacent condensing pots, the connection between the two luted, and the wood arranged in the usual way for charring. During the combustion of the wood the heat was sufficient to set free the metal which collected in the bottom pot. This method of distillation *per descensum* was extremely wasteful. In 1635 there was a fixed establishment erected, and the gallery furnace analogous to that at the Palatinate, which shall be described further on, adopted; in 1750 the Almaden system was introduced—and, finally, at the close of the last century, the aludel furnace was substituted by the present arrangement. The commencement of the present Idrian process is the assortment of the ores into two classes, according to the size of the pieces. All from the size of a cubic foot to that of a nut belong to No. 1; smaller pieces, and the dust, to No. 2. In No. 1 are further subclassified—*a*, the poorest portions, yielding only about one per cent.; *b*, the pure sulphide, yielding nearly eighty per cent.; and *c*, fragments of various richness averaging from one to forty per cent. The subclasses of No. 2 consist of—*d*, fragments from the mine, yielding from ten to twelve per cent.; *e*, particles separated on the sieve, yielding about thirty-two per cent; and lastly, *f*, the *schlich* obtained from the washings, containing eight parts of the metal in a hundred.

Figs. 359 and 360 are a plan and elevated section of the great distillatory furnace erected at Idria. In the latter figure only one of the furnaces are seen, although there are two in the same block with a double row of condensing chambers, as represented in the plan. *a a′*

are the fire doors; *b*, the hearth where the fuel is consumed, and above which is the body, *d*, of the furnace, divided by perforated arches into three compartments, the top one being in communication with the first condensing chamber on either side, by flues, $e\,e'$. There are

Fig. 359.



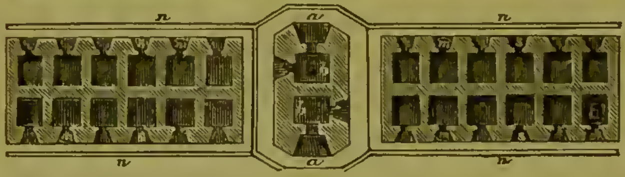
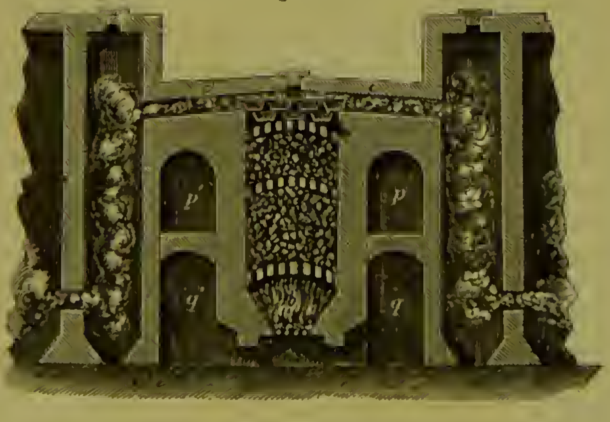


Fig. 360.

six chambers at each side of the furnace, *f*, *g*, *h*, *i*, *j*, *k*, *l*, the connection of one with another being placed alternately near the top and bottom, as at f', g', h', i', j', and k', with the view of bringing the vapors over as much space as possible, that in the course of which they might deposit the quicksilver. Each of these chambers has an outlet, *s*, by which the condensed metal flows out into a receiver, *m m*, whence it is conducted by a conduit, *n n*, into the main tank. They have likewise an aperture at the top, which is closed, as also that at the base, during the period that the furnace is working. The last chamber in the series is usually furnished with a number of flanges, or inclined boards, which reach in a slanting direction almost to the opposite wall, upon which a stream of water is continually falling from the top, so that the vapors, as they ascend through it, follow a sinuous course, and deposit the last traces of metal as they meet the flanges. $p\,p'$, $q\,q'$, are arches which conduct air to the fire and interior of the furnace, for the oxidation or burning of the sulphur. By side-doors opening into the several compartments of the furnace, the ore is introduced; these are closed whilst the charge is being fired. The largest and poorest pieces of ore are placed on the first arch, and the smaller ones in overlying beds till this part is full; in the next, the smaller fragments, which, however, allow sufficient space for the passage of the vapors, are deposited, and the upper compartment receives a number of earthen trays filled with the fine powder or *schlich*. All the spaces being thus replenished, and the doors and other apertures, where an escape would be possible, secured and luted, a brisk fire of beech or fir wood is made on the hearth, *b*, and maintained till the furnace acquires gradually a cherry-red heat; it is then kept at this degree for ten to twelve hours, during which the distillation lasts. The high temperature of the developed vapors, coupled with the great height of the furnace—about thirty feet—and the number of chambers that are in connection with it, create at the first a quick draught, which is sustained while the distillation continues. This is absolutely necessary, in order to draw as much air into the furnace as will suffice for the oxidation of the sulphur into sulphurous acid, and its removal from the metal. All the products of combustion, as well from the ore as from the fire, pass into the chambers, where they condense in part, the mercury falling upon the inclined slabs at the bottom, and collecting there, and the portions of cinnabar and mercurial soot forming upon the walls. The furnace is allowed five or six days to cool and condense the metal, at the end of which the upper apertures are opened, the portion condensed on the bottom drawn off, the walls brushed down, the separated mercury collected with the rest, and the grey powder and cinnabar gathered and put to one side, to be worked up in the next charge. This done, preparation is made to recharge and repeat the same process just described. One charge a week is the most that can be worked under these circumstances, and this charge, for the double furnace, amounts to ten or twelve hundred quintals, of one hundred and eight pounds avoirdupois each. A gang of forty men are employed in the charging, and the work lasts them three hours.

Fig. 361.



The yield of each charge averages eighty to ninety quintals of metal.

Lastly, the mercury is filtered through ticking cloth, and is then packed in cast-iron bottles for exportation. Each bottle contains sixty pounds. Only one such operation as has been described, can be effected weekly, since five or six days are required to cool the furnace, which is one hundred and eighty feet long, and thirty feet high.

Much inconvenience and injury attend the workmen at this establishment, owing to the dangerous effects of the mercury, inhaled whilst brushing down the walls of the chambers,—an operation which exposes the men to the vapors for two hours. Hence, it is no strange occurrence to observe many of the operatives salivated or affected with nervous tremblings.

Dumas suggests, that to make the establishment at Idria continuous in its operations, it would be necessary only to multiply the chambers of condensation, and substitute for the furnace at present erected, another on the principle of a continuous lime-kiln, the ore being charged in large pieces, and the *schlich* worked up into bricks or balls with clay, and introduced into the upper part. With such modifications this method would be, according to the last mentioned *savant*, the best in use; but the writer can hardly help thinking with Ure, that it is most unchemical in its present aspect, and out of keeping with what might be supposed to exist in these, the second most extensive quicksilver works in the world.

A different system to that followed at Almaden and Idria, as well in principle as in manipulation, is pursued in the mercury smelting works of the duchy of Deux Ponts. In the former, the principle of the changes is the removal of the sulphur by its combustion into sulphurous and sulphuric acids, and with this view the furnaces are constructed, so that the air is freely drawn through them at the temperature necessary to cause the expulsion of the sulphur. In the latter, the same ends are attained—not, however, by roasting, but by the addition of bodies which take the sulphur from the valuable metal, by a process of chemical decomposition. Lime is the body always resorted to, it being the most plentiful and cheapest; but scales or grains of iron would likewise answer, and the heat causes the formation of a sulphide of calcium or of iron, and sets free the mercury which is driven off in vapor, thus :—

$$\underbrace{4\,\text{Hg S}}_{\text{Sulphide of mercury.}} + \underbrace{4\,\text{Ca O}}_{\text{Lime.}} = \underbrace{4\,\text{Hg}}_{\text{Mercury.}} + \underbrace{3\,\text{Ca S}}_{\text{Sulphide of calcium.}} + \underbrace{\text{Ca O SO}_3}_{\text{Sulphate of lime.}}$$

that is, four equivalents of sulphide of mercury, and four equivalents of lime, afford the whole of the metal, three equivalents of sulphide of calcium, and one of sulphate of lime. This decomposition is more complex than that effected by roasting, as may be seen from the following formula:—$\text{Hg S} + \text{O}_2 = \text{Hg} + \text{SO}_2$. But the volume of hot gaseous matter from which the mercury is to be condensed, necessitates the use of an extensive range of cooling media, whereas, in the distillation with lime, these are not required, as only the metallic vapors are emitted.

In the duchy of Deux-Ponts, mercurial ores, mixed with lime, are heated in earthenware retorts furnished with receivers of the same material. A vertical section of the furnace gallery of the Palatinate is shown at Fig. 362. AA represent earthen cucurbits with their receivers, BB. Each of the former is filled about two-thirds with a charge containing ore and quicklime in the proportion of sixty to sixteen, and the receivers are at the same time half filled with water. The retorts are arranged in a double row, one above the other. In this way from thirty to fifty-two cucurbits are included in one *gallery*. The fire, which is from pit-coal, is placed on a grate beneath them, and a draft is secured by means of apertures in the arched roof. When the mercurial gangue is sufficiently calcareous, it is only necessary to moisten and distil it. As soon as the mass in the retorts is exhausted, the contents of the receivers are emptied into a wooden basin standing over a bucket; the object of this operation being to draw off, along with the water which falls over the sides of the bowl, all the black sulphide with which the metal is mixed up. This black matter is afterwards taken up, dried, and again distilled with excess of lime.

Fig. 362.

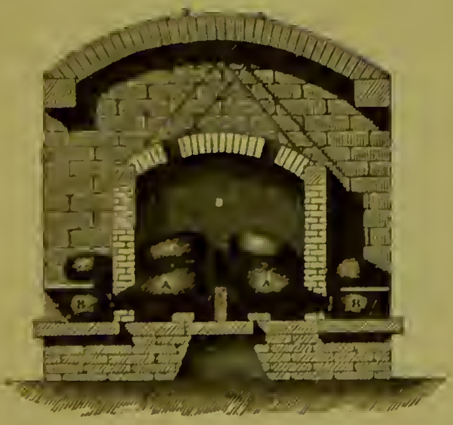


Fig. 363.

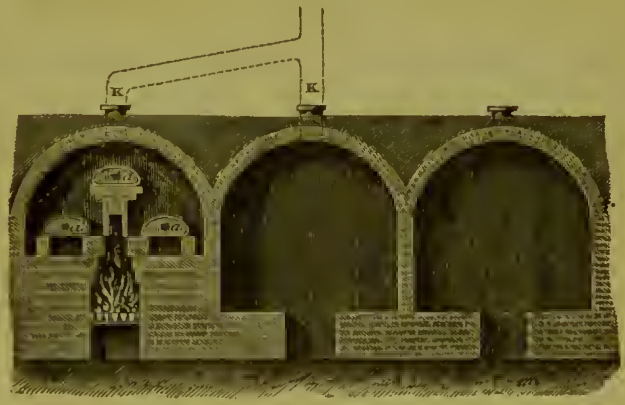
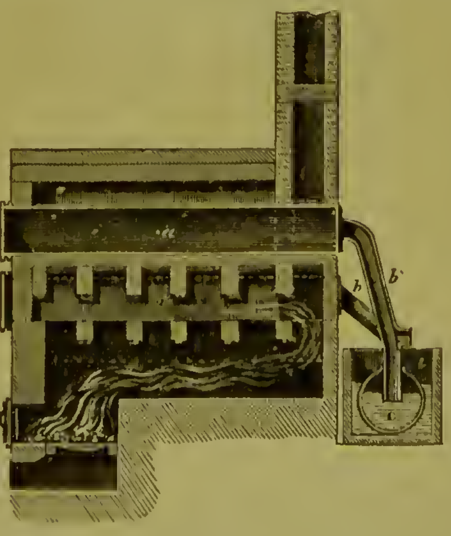
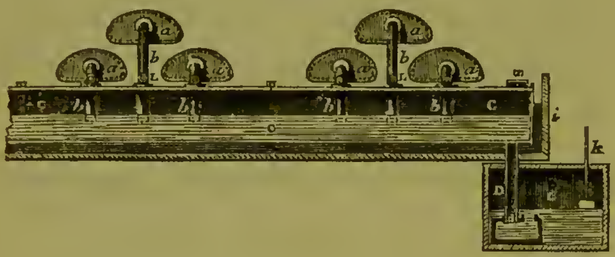


Fig. 364.



Method pursued at Lansberg.—One other metallurgic apparatus for the reduction of mercurial ores, remains to be described. It is in use at Lansberg, near Obermoschel, in the Bavarian Rhein-Kreis, where it was erected in 1847, and is the contrivance of the late Dr. Ure, who has thus figured and described it:—Fig. 363 is a section parallel to the front elevation of three arched benches of retorts. Each bench contains three of these vessels, *a a a*, constructed of cast-iron, and somewhat like those employed in the manufacture of coal gas; the whole are set in masonry, the bottom of the uppermost retort being protected from the direct impingement of the flame by fire tiles. The dotted lines leading to K K, show the direction of the chimneys. In Fig. 364, is represented in section the body of one of these retorts. The mouth on the right of the figure is closed with an iron lid, which is bolted, barred, and luted, after the charge has been introduced. An iron pipe, four inches in diameter, and having a nozzle hole at L, dips into the main condenser, C, and the same arrangement is shown at another section at Fig. 365, where C C gives a longitudinal view of the main condenser, which consists of a pipe twenty feet long, and eighteen inches in diameter. The backs of the retorts are shown at *a a*, and the eduction-tubes in the same figure at *b b*, dipping a short way beneath the surface of the water. At *z* is placed a water valve to obviate the risk of sudden expansion or condensation from inequalities of temperature, and at *i* is depicted a water trough, or outer vessel of wood, in which the condenser is placed. The inclination of the condenser is towards the left, so as to favor the exit of the mercury by the vertical delivery tube, D, into the lock-up reservoir, *e*. The end of this tube dips from the first into a small cistern of mercury, and at *k* is shown a floating and graduated gauge rod by which the quantity of mercury in the chest, *e*, may be always ascertained without the trouble of opening it.

Fig. 365.



Before charging the retorts, the ore is reduced to a coarse powder, then mixed with quicklime, and shovelled in. Six or seven hundredweight of the mixture, a sufficient charge for each retort, can, with a proper amount of heat, be worked off in about three hours. The process is continuous, and, with an efficient staff of workmen, could be daily made, by using nine such retorts, to decompose six tons of the mixture—a quantity which, if the ore was rich like that of the Idrian or Almaden mines, would equal twelve hundred to a ton of mercury daily.

It is singular that the imperfect process of condensation by such barbarous apparatus as *aludels*, or the rude and cumbrous furnaces of Idria, should not have been superseded by an arrangement similar to, or equally efficient with, that just described. The outlay would be repaid in the course of a few months by the expedition with which continuous yields of metal could be obtained, and an enormous saving would take place through the complete condensation of the metallic vapors; whilst the duties of humanity would be attended to, and many, if not indeed all, of the miserable results of a poisoned atmosphere, would be avoided.

Purification of Mercury.—If, as is sometimes the case, the mercurial ore contains bismuth or zinc, portions of these metals will be carried over with the distillate. Lead, antimony, and tin, may also be present as adulterations, having been fraudulently introduced. Various methods have been devised for rendering the metal chemically pure. WITTSTEIN recommends, where not more than three pounds are operated on at once, that its redistillation should be effected in a small plain retort of thick glass, clean iron turnings being added to the mercury, in the proportion of one of the former to twelve of the latter. The retort rests in a deep sand bath, which is placed in a furnace; as much inclination as possible being given to the neck of the vessel, which should be lengthened with a cylinder of stout paper. The end of the paper tube dips into a receiver nearly full of water, which, again, rests on a ring of straw placed at the bottom of a larger vessel, also filled with water. The heat being assisted by wood and a chimney, now causes the mercury to boil, and its vapour, condensing, rolls down the paper tube and collects in the receiver. As soon as it is cold, the water is poured off, and any trace of iron, or of oxide of mercury, which generally appear as a thin film, is readily removed by hydrochloric acid. The mercury is then well washed in water, dried at a gentle heat, or run through bibulous paper till it ceases to damp it; after which it may be passed through a cone of writing paper, having a very small aperture, which removes all traces of mechanical impurity. Or, instead of glass, a wrought-iron mercurial bottle may be employed. This bottle should never be more than half full, and must be fitted with an iron delivery tube, to the end of which a canvas pipe is attached, on which a jet of water is directed; the condensed mercury falls into a vessel. A second method is by treatment with strong sulphuric acid. This is best effected by covering the metal with its own volume of concentrated oil of vitriol in a flat glass or porcelain dish, stirring repeatedly with a glass rod, and leaving the metal and the acid in contact for six or seven days. Pure mercury, as has been already said, is not attacked by this acid, and digestion in the cold has merely to be repeated with successive portions of oil of vitriol as long as sulphurous gas is given off, or the liquid shows any symptoms of turbidity. It is certain that by this process even lead may be removed, although, under ordinary circumstances, that metal is but little attacked by strong cold sulphuric acid. But, in the first place, the lead in this case is in the form of amalgam, which implies minute subdivision of its particles, and at the same time the tendency of the acid towards the lead appears to be increased *by the presence of the mercury*. Such metals as gold, silver, and platinum, which are not acted on by sulphuric acid, cannot, of course, be separated from mercury, except by distillation.

A third method is to heat the metal for several hours to 130°, with a small quantity of commercial nitric acid diluted with twice its volume of pure water. The foreign metals being more easily oxidised than the mercury, are dissolved, and this operation having been repeated as often as required, the purified metal is then washed and dried.

A solution of nitrate of mercury may be substituted for one of nitric acid. In this way an equivalent of metal is deposited for every equivalent of more oxidisable metal which is removed. These nitric processes are, however, liable to this disadvantage, that the foreign metals can only be completely removed when some mercury remains in solution.

The process recommended by MELLON, and which REGNAULT employed to obtain pure mercury for his third determination of its density, is as follows:—He first agitated the metal for some time with weak nitric acid, using for two pounds of mercury an ounce and a half of acid and two ounces of water. By this means all the more oxidisable metals were acted upon. The solution containing these having been poured off, the mercury was again digested with strong nitric acid, till nine-tenths of it was dissolved. The resulting nitrate was converted thereafter into mercuric oxide, which, in its turn, was changed by heat into the metallic form. All traces of oxide having been removed by agitation with strong oil of vitriol, the product was carefully washed and dried *in vacuo*.

Dr. PRIESTLEY gives, in his *Observations on Mercury*, a simple process by which effectually to separate quicksilver from lead and tin. He employed continued agitation, with fresh portions of air supplied by repeatedly blowing into a small glass phial, in which the mercury was actively shaken. A little powdered sugar very much assists this process, by mechanically collecting and retaining on its particles the portions of foreign oxides as they are produced. The fluid metal may then be run through a cone of paper, having a very minute aperture at the bottom, by which all the solid particles, including dust, fibres, *et cetera*, are retained.

Other methods might be resorted to, such as the decomposition of the factitious cinnabar by heat and iron filings, or of the commercial red precipitate alone by heat, with the subsequent removal of all adhering oxide, by means of sulphuric acid. Or the metal may be sublimed along with one-tenth of its weight of powdered vermilion; or, according to the method of ULEX, two pounds of mercury may be agitated with half an ounce of solution of sesquichloride of iron; specific gravity 1·48. Ten minutes suffice to remove all metallic impurities of the ordinary kind, a result which the finely divided state of the metal seems to favor. Lastly, VIOLETTE proposes to make use of highly-heated steam. It is a well-known fact that when this metal is boiled with water in a flask, mercurial vapor rises, and is carried off with the steam. The distillation of mercury by the method of VIOLETTE has especial reference to its removal from silver in smelting houses. The process is said to effect a considerable saving of fuel, and of the health of the workmen. It is performed by bringing the steam up to 700°, in its passage through a worm, from which it enters the vessel containing the mercury, dipping a little way beneath its surface, and soon causing the metal to boil; after which the mercurial and aqueous vapors are carried off, and suitably condensed.

It may be here remarked that pure mercury is entirely volatilized in the heat; it dissolves completely in nitric acid, producing a nitrate of the metal, which, when the acid is employed in excess, is easily soluble in water. Poured into a narrow glass vessel, it presents a convex surface, owing to the mutual attraction of glass and mercury being at best but feeble; if, however, the metal be amalgamated with as slight a quantity as the one four-thousandth part of lead, the convexity of the pure metal is destroyed, and the surface becomes even.

Physiological Effects.—It has long been a matter of doubt and discussion whether this metal exercises any physiological effects upon the human system, analogous to those of most of its saline compounds. It is generally admitted that, when taken in compact masses, the metal does not exert a poisonous action, although it may occasion injury mechanically; but when in a finely attenuated state, as in vapor, or *deadened* with innocuous substances, it possesses the power of manifesting all the symptoms of a mercurial poison.

All the effects of mercurial poisoning are very frequently observed among the miners and smelters of this metal, as also in those who work with water-gilders, looking-glass and barometer makers. For the most part they appear as the disease known as the *mercurial trembling*, or a kind of palsy, which first manifests itself by an unsteadiness in the arms, and which goes on till the movement becomes convulsive, and vertigo, loss of memory, and other cerebral disorders, which generally terminate fatally, follow. When the symptoms develope themselves in a mild form, and the individual perseveres in his labors, they proceed, and never fail to become more violent, and endanger the life of the person. This is well known in the mercurial mining and smelting districts, where if once a man becomes affected with trembling or salivation he is removed to a less dangerous department, or disbanded altogether. Some physiologists have remarked that the circulation is usually depressed and slow when the patient is undergoing salivation, and exhibits other symptoms of the effects of mercury; whilst others have observed an excited state of circulation, a fetid breath, with metallic taste in the mouth, increased flow of saliva, and a sponginess of the gums proceeding to ulceration, which sometimes extended to the throat.

Vegetal physiologists state that mercurial vapor is destructive in a high degree to the life of plants.

MERCURIAL COMPOUNDS.—Mercury is capable of combining with most of the non-metallic elements, and many of the compounds thus formed are capable of constituting ingredients in further combinations; it has, therefore, a wide range of affinity, but in a manufacturing sense most of those compounds are unimportant, although in a strictly scientific point of view, and also on account of their medicinal qualities, they sometimes attract a great deal of attention. The principal compounds of mercury to be considered here are the sulphide—*cinnabar*, *vermilion*—the chlorides, oxides, iodides, *fulminating mercury*, and the ammonio-mercurial chloride known as *white precipitate*. The oxides, though not the most important, will be noticed first.

OXIDES OF MERCURY.—As stated already, there are two oxides of mercury, the *sub* and *prot*-oxide, which are capable of yielding well-defined salts of the respective bases. The first of these is not so stable as the second, nor is it so important in its applications.

Suboxide of mercury was first scientifically described in 1797; but was known, probably, long before that period as the *æthiops per se* of the pharmaceutists. There are several methods for preparing it; the simplest and readiest being the precipitation of a dilute solution of a subnitrate of mercury by potassa; or it may be formed by disseminating calomel in water, and adding a proportionate quantity of potassa to the liquor, when suboxide of mercury falls. The change may be expressed thus:—

$$\underbrace{Hg_2O\ NO_5}_{\text{Subnitrate of mercury.}} + \underbrace{KO}_{\text{Potassa.}} = \underbrace{Hg_2O}_{\text{Suboxide of mercury.}} + \underbrace{KO,\ NO_5}_{\text{Nitrate of potassa.}}$$

Or,

$$\underbrace{Hg_2\,Cl}_{\text{Subchloride of mercury.}} + \underbrace{KO}_{\text{Potassa.}} = \underbrace{Hg_2O}_{\text{Suboxide of mercury.}} + \underbrace{KCl}_{\text{Chloride of potassium.}}$$

All the operations connected with this compound should be performed out of diffused daylight; and care must also be taken that the precipitation be complete, otherwise the substance thrown down will consist of a mixture of suboxide, protoxide, and metallic mercury.

After being thoroughly washed, to remove alkalinity, and dried in the dark, suboxide of mercury is a black powder, having a disagreeable odor—Gmelin says it is devoid of taste and smell—it is insoluble in water and alkalies, soluble in nitric and acetic acids, and has a specific gravity of 10·6, Herapath; 8·95, Karsten. It is very rapidly decomposed, when exposed to the light of the sun, into protoxide and metallic mercury; but the same change, though slowly, is effected in the darkness. Heat resolves it into oxygen and metal. It is also decomposed by many compounds, the mercury being taken into other states of combination, and sometimes set free. Its composition is expressed centesimally by

	At. weight.		Donovan.	Gulbourt.
2 Eqs. of mercury,....	200 ..	96·15 ..	96·04 ..	95·69
1 Eq. of oxygen,.....	8 ..	3·85 ..	3·96 ..	4·31
1 Eq. suboxide of mercury,........	208	100·00	100·00	100·00

The suboxide of mercury is converted to no particular use in the arts.

Protoxide of Mercury.—This is the *precipitatum per se*, or calx of mercury, mentioned in old writings; it is analogous to the *hydrargyri oxidum rubrum* of modern pharmacy. Protoxide of mercury has an interest attached to it much greater than its application in the arts would merit, owing to the knowledge of its nature and composition being contemporary with the discovery of oxygen, the subversion of the old phlogiston theory, and the introduction and pursuit of a new and more enlightened system of chemical science. It was formerly prepared by submitting mercury to a high temperature in a narrow-necked flat-bottomed mattrass, known as Boyle's *hell*, when, after a long period, the metal was slowly converted into oxide. This process is now, however, quite abandoned; salifying the metal, and subsequent precipitation of the oxide, being considered more effectual. One part of mercury is treated with three parts of nitric acid, specific gravity 1·20, in a flask on the sand bath, till perfect solution takes place, and the solution evaporated to dryness, the residue mixed up with another part of the metal, and the whole heated again as long as nitrous fumes are observed to pass off. The residue, which now appears a dull grey mass, is removed from the heat, mixed with a tenth of its weight of pure crystallized carbonate of soda, and the whole boiled with water for a quarter of an hour, when impure protoxide of mercury settles to the bottom, and this by filtration and washing may be converted into pure protoxide—*red oxide of mercury.* The nitrate of mercury alone may be submitted to heat in this operation, but a loss of nitric acid would take place; besides, the degree of heat is critical, so that it is more productive and less troublesome to proceed as above stated. By the following formula the changes of the substances here alluded to are expressed:—

$$\underbrace{6\ Hg}_{\text{Mercury.}} + \underbrace{8\ (HO,\ NO_5)}_{\text{Nitric acid.}} = \underbrace{(6\ HgO.\ NO_5)}_{\text{Protonitrate of mercury.}} + \underbrace{2\ NO_2}_{\text{Nitric oxide.}} + \underbrace{8\ HO}_{\text{Water.}}$$

And secondly—

$$\underbrace{3\ (2\ HgO,\ NO_5)}_{\text{Subnitrate of mercury.}} + \underbrace{6\ Hg}_{\text{Mercury.}} = \underbrace{12\ HgO}_{\text{Oxide of mercury.}} + \underbrace{3\ NO_3}_{\text{Nitrous acid.}}$$

Oxide of mercury prepared by the action of heat upon a protosalt of the metal, forms a shining brick-red crystalline scaly powder, which, on being pulverized, acquires an orange tint. By the action of a moderate heat it changes to a vermilion color, which passes as the temperature rises to a darker hue, approaching to black, but as the substance cools the natural shade is regained. The specific gravity of the red powder has been variously estimated, the number arrived at by Playfair and Joule being 11·136. It is but slightly soluble in water, only one part being taken up by seven thousand parts of this liquid; the solution, however, has a disagreeable metallic taste, and exhibits an alkaline reaction to delicate color tests; but alcohol fails to dissolve it. Between 700° and 900° it is resolved into its elements. Oxide of mercury obtained by precipitation is an amorphous yellow powder, and in this differs from that obtained by heat. There are also many other reactions wherein they behave differently.

The protoxide is readily decomposed by several substances; even light is capable of resolving it into mercury and oxygen gas; heat, and all organic substances, produce the same effect, only much more quickly. On this account it is frequently employed by the analyst to remove the last traces of carbon from a substance, and to oxidise sulphur into sulphuric acid. Phosphorus, sulphur, sulphurous acid, the alkali metals, protochloride of tin, and several other bodies, decompose it, many of them with evolution of light and heat. The protoxide of mercury may be distinguished from the suboxide, first by its color, and secondly by its solutions not giving a white flocculent precipitate with hydrochloric acid; it also produces, with solutions of hydriodic acid, or of alkaline iodides, a beautiful scarlet precipitate of iodide of mercury, and which is characteristic compared with the dull green color of the subiodide. Potassa gives a yellow, and ammonia a white precipitate, both of which are sufficiently distinct from the black deposit that they afford in solutions of the suboxide of this metal.

Protoxide of mercury is composed of—

	At. weight.	Centesimally. Theory.	Donovan.	Erdman and Marchand.
1 Eq. of mercury, ...	100 ..	92.59 ..	92.75 ..	92·596
1 Eq. of oxygen, ...	8 ..	7·41 ..	7·25 ..	7·404
	108	100·00	100·00	100·000

Its chemical symbol is $Hg\,O$.

It is stated that protoxide of mercury is occasionally adulterated with minium or red lead, sesquioxide of iron, and powdered brick. Such substances are readily detected by heating the substance to a dull heat; the protoxide of mercury sublimes, and leaves the non-volatile matters in the crucible, or the mercurial compound may be treated with dilute nitric acid, to dissolve the mercurial oxide; and should minium be present, a puce-colored binoxide of lead remains together with the other adulterants, if any be present. On adding dilute sulphuric acid to the clear liquor obtained in the foregoing, a white precipitate of sulphate of lead falls, corroborative of the existence of a lead compound.

SULPHIDES OF MERCURY.—Sulphur and mercury are capable of uniting artificially, and of forming compounds analogous to those produced from this metal with oxygen.

The subsulphide is the *æthiops mineral* of the older chemists, and was prepared by agitating a little water, sulphur, and mercury, in equal proportions, in a mortar, or at a slightly increased heat, till a black powder resulted. It can be obtained by transmitting a stream of sulphide of hydrogen gas through a dilute solution of subnitrate of mercury in the cold, when a subsulphide of a black color falls. The reaction is as follows:—

$$Hg_2O, NO_5 \;+\; HS \;=\; Hg\,S, \;+\; HO, NO_5$$

Heat must be guarded in this operation, since it would resolve the subsulphide into a protosulphide of mercury and metal, thus—

$$\underbrace{Hg\,S}_{\text{Subsulphide of mercury.}} \quad = \quad \underbrace{Hg\,S}_{\text{Sulphide of mercury.}} \quad + \quad \underbrace{Hg}_{\text{Mercury.}}$$

Prepared by either method, this compound appears as a black, tasteless, inodorous powder, which is insoluble in water, in hydrochloric, and dilute nitric acids. By heat it is resolved into mercury, and the red sulphide of the metal—cinnabar. Its chemical composition is—

	At. weight.	Centesimally.
2 Eq. of mercury, ...	200	92·59
1 Eq. of sulphur, ...	16	7·41
1 Eq. of subsulphide of mercury,	216	100·00

This compound is not prepared in any quantity, nor has it any application, excepting among veterinary surgeons, and even these are abandoning it for more appropriate agents.

Protosulphide of Mercury.—Cinnabar, Vermilion.—This is a much more important compound, though, like the former, medicinally inert. The character and composition of the native ore have been already explained. Only a small quantity of that mineral, however, is of sufficiently fine quality to permit of its being employed as a pigment. Chemically, there is no difficulty in forming it; but its value in the arts depends upon the richness of its color, the exact conditions to insure which are far from being generally understood. The following are some of the processes for its preparation:—

When sulphide of hydrogen gas is passed to saturation through a solution of protoxide of mercury, the white compound which appears at an early stage of the operation is destroyed, and the black precipitate then consists solely of mercuric sulphide, which, when collected, dried, and heated in a retort, yields a fine crystalline sublimate of cinnabar. These two bodies, therefore, the black and the red, are allotropic modifications of one substance, $Hg\,S$.

The process of LIEBIG consists in forming the *white precipitate* $Hg\,Cl$, $Hg\,N\,H_2$, and digesting it with sulphide of ammonium, obtained by saturating the common alkaline hydrosulphide with sulphur. The color of the product he afterwards improves by boiling with caustic potassa.

KIRCHOFF recommends triturating one hundred parts of mercury in a porcelain dish, with twenty-three parts of flowers of sulphur, chemical action being assisted from time to time by moistening the mixture with solution of caustic potassa. A potassa lie, containing fifty-three parts of solid hydrate in fifty-three of water, is next prepared, and in it the sulphurised mercury is warmed, and further triturated. The water must be replaced as it evaporates, and the operation continued for two hours. After this, and still with trituration, the red mass is evaporated to a thin paste, removing the heat at the moment when the red color has attained its finest shade; for a few seconds, either too soon or too late, deteriorates the quality of the product. Too little heat fails to bring up the red to its utmost degree of brightness, and a little too high, or even too long continuance of the proper temperature, changes the color to brown, and it can never be restored. The product, when cool, is *first* washed with a solution of potassa, and *afterwards* with water.

URE, in alluding to the process of KIRSCHOFF, remarks that of late it has been so much improved that the vermilion which it yields quite equals in tint that made in China. It appears also by the following table, that the quantity of vermilion which can be obtained, depends on the relative proportion of the substances employed:—

Mercury.	Sulphur.	Potassa.		Vermilion.
300	114	75	yield	330
—	115	75		331
—	120	120		321
—	150	152		382
—	120	180		245
—	100	180		244
—	60	180		142

BRUNNER directs the trituration of one hundred parts of mercury with thirty-eight of sulphur. The æthiops so produced is next heated to 113° with twenty-five parts of potassa in one hundred and thirty-three to one hundred and fifty parts of water, and more liquid supplied as it becomes reduced by evaporation, the mixture being kept occasionally stirred. After a few hours the black substance begins to take a brown tint, and if the heat be maintained at 113° to 118°, this goes on brightening till it becomes a lively red. Whenever the mixture becomes gelatinous, more water must be added, for it is absolutely necessary for the success of the process that it be kept in as pulverulent a state as possible, and also that the heat rise not above 120° to 122°. When the product has attained the fine red required, and which happens in the course of eight hours, the fire is removed, and the contents of the vessel are left to cool slowly. The cinnabar is then removed, washed with water, and further purified by levigation from any mercury or black sulphide which might still remain. BRUNNER states that one hundred parts of mercury, forty parts of sulphur, and forty of potassa, afford one hundred and seven parts of vermilion little inferior to the finest native substance, and much superior to any obtained by sublimation.

Dutch Method of Making Vermilion.—It is well known that the monopoly of preparing this pigment was long held by the Dutch, who alone, at one time, possessed in Europe the secret of giving to it a rich scarlet color. The particulars of the old method of its preparation at Amsterdam were many years ago described by M. TUCKERT in the *Annales de Chimie.* The process consisted of two parts; first, the production of what M. TUCKERT terms æthiops, but which is a mixture of cinnabar, black sulphide, uncombined metal, and sulphur; and, second, the conversion of this into the pure vermilion.

The first part of the operation was to effect the combination in a flat polished iron pot, two and a half feet in diameter, and one deep. Into this, one thousand and eighty pounds of mercury and one hundred and fifty pounds of sulphur—equivalent to 87·8 of mercury and 12·2 of sulphur, per cent.—were introduced, and the mixture stirred with an iron spatula very cautiously, because if the components were too briskly mingled, the combination would be too violent, and some of the substances would be lost. The black product of this operation, being reduced to powder, was next placed in hand jars capable of holding one pound and a half of water—thirty to forty of them being constantly kept full. The subliming pots, three in number, which were made of pure sand and clay, and well luted outside, were each covered with a smooth iron lid, and placed in a furnace secured with hoops of iron; the position of the pots being such that the flame could play over two-thirds of their height. In the evening the operation of heating the pots was begun, and as soon as they attained a red heat the iron covers were removed, and a pipkinfull of black sulphide thrown into each, and there left to crackle and burn. This emptying of the smaller pots into the larger was continued—sometimes two or more being emptied into the subliming pot at once, till, in the course of thirty-four hours, four hundred and ten pounds had been emptied into each of the three. As each fresh portion of black matter was thrown in, the mixture took fire, and the flame rose from three to six feet above the edge of the pot. During this period the cover was not replaced; but as it subsided the pot was again covered with the iron plate, until it was necessary to remove it for the introduction of more sulphide. For thirty-six hours after the last portion was added, the same steady heat was continued, and the contents of the pot occasionally stirred by means of an iron rod which passed through the top of the lid. During this period, also, the workman tested from time to time the security of the process, by cautiously removing the pots, and observing to what height the flame then rose, and with what vigor it burnt. The proper temperature was indicated by a vigorous combustion, accompanied by a flame, which did not rise more than three or four inches over the edge of the pot.

When the thirty-six hours were expired, the whole was allowed to cool, after which the pots were removed and broken, and the vermilion which was incrusted within them, and chiefly in their upper parts, collected, ground with water between horizontal stones, then passed through sieves, and thereafter elutriated and dried. The usual loss in converting the black sulphide by this process into vermilion, was nearly three per cent.

Method adopted at Idria.—At Idria, as already stated, large quantities of the sulphide of mercury pigment are annually prepared. The method pursued is to introduce into a number of well-bound casks, contrived to turn on their axes, eight pounds of sulphur and forty-two of mercury, and then to put them in motion for three hours or more, till the ingredients combine to form a brownish powder. A number of cast-iron cylinders, placed upright in a furnace and heated to dull redness, are then charged with this product, one hundred pounds being portioned to each, the weighted cast-iron cover being immediately fixed on, and retained till all crackling noise subsides. When this happens, the iron top is removed, and another of stoneware, having the beak connected with a tube and receiver substituted; at the same time the fire is increased for the purpose of expelling the sulphide of mercury from the iron cylinder. After the sublimation of the charge, the capital and tube are removed, and when cold, the cake of cinnabar is separated. That which has the brightest tint is found caked on the outside of the cover; the portion collected in the tube and receiver is generally mixed with an excess of sulphur, which volatilizes with it, and for the most part is returned with a fresh charge of æthiops to be re-sublimed. The cakes of cinnabar are broken, and ground finely with water; then boiled with a solution of potassa, washed first with hot, and next with cold water, and finally dried.

Chinese Vermilion, which is so rich in color as to command five or six times the price of the European product, appears to be prepared in the ordinary way, leaving nothing to account for the superior brilliancy of shade except the sunnier climate. By careful selection, the finest portions are collected, and, if necessary, ground and washed several times. In making the artificial product, one part of sulphur and four of mercury are introduced into an earthen pot, to which an iron cover is luted and bound with wire; the pot with its contents is then placed in a fire of dried camel's dung. After sublimation, the cover is removed and the pot broken, and the purest of the sublimate picked out from the less-colored product, ground very fine, and the powder sifted into a large vessel of water. When the red product has subsided, the supernatant water and scum are drawn off, and fresh liquid supplied, in which the sediment is stirred up, and after subsidence, the substance is collected and carefully dried in the sun.

By subliming one part of sulphide of antimony with sulphide of mercury, a greyish cinnabar is obtained. On boiling this with a solution of *liver of sulphur*—a compound of sulphur and potassium—and afterwards with hydrochloric acid, and washing thoroughly with water, a product is obtained which is quite as brilliant as the finest Chinese vermilion, and retains no antimonial sulphide. Sulphide of mercury prepared by saturating a solution of oxide of mercury, is a black substance, but when prepared by the other processes mentioned, it has a red color, more or less lively. It is a soft, heavy, colorless, and tasteless powder if prepared by the moist method, and is devoid of crystalline structure, but the sublimed product appears in masses composed of hexahedral needles. Exposed to the light of the sun it gradually acquires on the surface a grey tint, owing to a portion being decomposed into mercury and sulphur.

Properties.—Water or alcohol have no action upon cinnabar. Cold hydrochloric and nitric acid singly fail to dissolve it; but nitro-hydrochloric acid readily attacks it and converts it into chloride. Nitric acid, when heated, decomposes it, and produces a proto-sulphate of oxide of mercury and sulphur. Caustic potassa or soda in solution does not decompose cinnabar; but if the hydrate of the alkali be employed, and its action be assisted by increased temperature, decomposition takes place, which results in the production of metallic mercury, sulphate and sulphide of the alkali.

A temperature approaching a red heat volatilizes it without decomposition; if air be admitted the sulphide burns, the sulphur being converted into sulphurous and sulphuric acids, and the metal disseminated in the vapor. Charcoal, and other carbonaceous matters, iron filings, lime, or any of the fixed alkaline bases, also abstract the sulphur and set the metal free.

Cinnabar is composed centesimally, according to the analyses of Proust and Guibourt compared with theory, as follows:—

	At Weight.	Theory.	Proust.	Guibourt.
1 Eq. of mercury,............	100	86·21	85·0	86·21
1 Eq. of sulphur,............	16	13·79	15·0	13·79
1 Eq. of sulphide of mercury,.	116	100·00	100·0	100·00

These determinations lead to the formula $Hg\,S$.

Cinnabar or vermilion is principally employed for its hue, and is but rarely prescribed by the physician. Its high price exposes it to considerable sophistication in the hands of unprincipled traders. The adulterations which are most likely to be contained in it are minium or red lead, ferro-ferric oxide, $Fe_3\,O_4$, red brick dust, and pentasulphide of arsenic. In searching for red lead in this case, the same directions as those given for the detection of the same adulterant in red oxide of mercury may be pursued; brickdust may likewise be detected in the way there directed; iron may be readily found by treating the residue, after the sublimation of the mercurial sulphide, with hydrochloric acid, and testing the filtered liquid with ferrocyanide of potassium—yellow prussiate—when a blue precipitate will appear if iron be present. Pentasulphide of arsenic may be found by treating the pigment repeatedly with strong solution of potassa, boiling, filtering off the liquid, adding to it hydrochloric acid, with a few fragments of zinc or iron, and, subsequently, transmitting sulphide of hydrogen gas through the solution, then boiling, filtering off the liquid, and adding hydrochloric acid to it to saturation. After some time sulphide of arsenic of a yellow color falls. In this case the alkali dissolves the quinquesulphide from the mercury compound, and the hydrochloric acid again effects its precipitation.

The pigmentary uses of cinnabar are not confined to its external application in painting. It is largely consumed in the manufacture of red sealing wax, in which it is mixed up with venetian turpentine, shellac, and colophony. It is also employed in coloring wafers, and has been for the same purpose used in confectionary, and to improve the color of cayenne pepper; a practice greatly to be reprobated, for although Mr. Taylor states that he has not been able to find any instance of its having acted as a poison on man, yet thirty to seventy grains, even applied externally, have proved poisonous to the lower animals. It can scarcely be said to be used medicinally at the present time, though in 1769, Dr. Dalby wrote a book in praise of the virtues of cinnabar and musk in the cure of hydrophobia. Bolley proposes a solution of the ammonio-nitrate of silver as a test for cinnabar, for with whatever other matters it may be mixed up as a coloring matter, an instantaneous black color is produced, resulting from the formation of sulphide of silver along with basic nitrate, and also amide of mercury.

Chlorides of Mercury.—It may be safely stated that of all the compounds of mercury, none are of greater importance, in a medicinal point of view, than the two compounds produced by the union of chlorine and mercury, and which are well-known by the title of *calomel*—subchloride of mercury—and *corrosive sublimate*—protochloride of mercury. It is the growing opinion that in whatever state of combination mercury is administered by the medical practitioner, the active effects are the result of the chlorides of the metal, these being formed by the chlorides and free hydrochloric acid of the stomach. The experiments of Mailhe tend to corroborate this view, and hence the two compounds of mercury and chlorine are the principal mercurial combinations to which attention is directed in the several pharmacopœiæ of the medical colleges. For this reason, various methods are given for their preparation, and also for ascertaining their purity.

Subchloride of Mercury—Calomel.—As stated under the ores of mercury, this combination is met with in several mines in the form of incrustations—horn quicksilver—on other ores, or disseminated in the form of small transparent and translucent crystals. Those mines where it is particularly noticed, are the Almaden, Idria, Moschellandsberg; the mines of the Palatinate, Deux Ponts, and Bohemia. The quantity so found is, however, unimportant, and the native substance is never applied in medicine, that which is artificially prepared being preferred. There are several methods by which subchloride of mercury may be obtained, as well by precipitation as by the dry way. When a solution of pure subnitrate of mercury is precipitated by another of a pure alkaline chloride, or with dilute hydrochloric acid, a white flocculent mass falls, which is the compound in question, and when washed well and dried it is chemically pure. It is necessary, however, to prolong the washings, otherwise some traces of the alkaline precipitant are retained, which react as a solvent upon a part of the precipitate by forming a double compound with it; and hence it is that calomel prepared in this way always leaves a mercurial taste. To guard against this, recourse is usually had to the dry method, in which the mercurial subsalt and chloride of sodium are mixed in the proper proportions, and then submitted to heat in a subliming pot, when the calomel is obtained in the form of a white incrustation on the cover of the vessel. Prepared in either way subchloride of mercury is a yellowish-white powder, which under the influence of solar light turns grey, being transformed into the protochloride and metallic mercury; it is but very slightly soluble, one part of the salt requiring twelve thousand of boiling water for perfect solution. Dilute hydrochloric acid has no action upon it, but when concentrated it changes the salt into metal and protochloride, thus—

$$\underbrace{Hg_2\,Cl}_{\text{Subchloride of mercury.}} + \underbrace{H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Hg}_{\text{Mercury.}} + \underbrace{Hg\,Cl}_{\text{Chloride of mercury.}} + \underbrace{H\,Cl.}_{\text{Hydrochloric acid.}}$$

Concentrated boiling solutions of the fixed alkaline chlorides, and of chloride of ammonium, react upon calomel in the same way. Hot strong nitric acid readily dissolves the subchloride of mercury, converting it into a protonitrate and protochloride of the metal. It is readily sublimed, and forms crystals on condensing. Its applications are chiefly medicinal, but it is employed in the laboratory as a test, though not frequently so used.

The symbol for this salt is Hg_2 Cl, corresponding with the suboxide Hg_2O; its atomic weight, $100 + 35{\cdot}5 = 135{\cdot}5$; its density, 59°·77.

The formula given above agrees with the following composition:—

	At. weight.	Contesimally. Theory.	Contesimally. Klaproth.
2 Eqs. of mercury,....	200	84·96	85·10
1 Eq. of chlorine,....	35·5	15·04	14·90
	235·5	100·00	100·00

	Volume.		Specific gravity.
Mercurial vapor............	1	=	6·9300
Chlorine	½	=	1·2271
Vapor of calomel	1	=	8·1571

Although CHRISTISON and other authorities assert, that the calomel prepared by precipitating a dilute solution of a subsalt of mercury with one of chloride of sodium in the manner already stated, or by agitating a solution of sesquichloride of iron with metallic mercury, does not differ in therapeutic properties from that formed by sublimation, still the latter method is adopted in the manufacture. Various recipes are known for obtaining it; thus, by mixing four parts of corrosive sublimate—protochloride of mercury—with three parts of the metal, and subliming, calomel is obtained; likewise, when sulphate of the protoxide of this metal is heated with an equivalent proportion of common salt and mercury, corrosive sublimate is produced. In the first instance the reaction may be symbolized thus—

$$\underbrace{Hg\,Cl}_{\text{Chloride of mercury.}} + \underbrace{Hg}_{\text{Mercury.}} = \underbrace{Hg_2\,Cl.}_{\text{Subchloride of mercury.}}$$

and in the second,

$$\underbrace{Hg\,O,\,So_3}_{\text{Sulphate of mercury.}} + \underbrace{Hg}_{\text{Mercury.}} + \underbrace{Na\,Cl}_{\text{Chloride of sodium.}} = \underbrace{Hg_2\,Cl}_{\text{Subchloride of mercury.}} + \underbrace{Na\,O,\,So_3.}_{\text{Sulphate of soda.}}$$

When operating according to the first equation, it is required to have the metal in slight excess, in order to insure the complete reduction of the protochloride. MOHR states that this method is frequently adopted in the German pharmaceutical laboratories. The materials are ground up with a little water, or spirit, to prevent the escape of dust or powder, and when the metal is *deadened* the material is placed in glass vials and heated; after sublimation the product is collected by breaking off the neck of the bottles, and detaching the crust of salt.

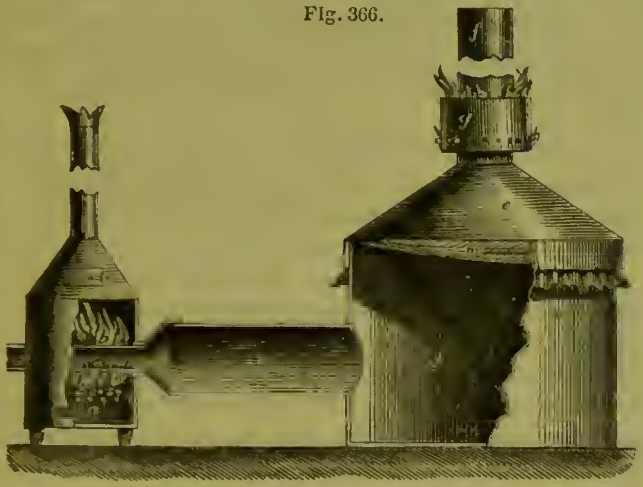
When preparing it by the second method, which is much the better of the two, two parts of mercury are dissolved in three of strong sulphuric acid, or better still, four ounces of the metal are acted upon with two ounces two drachms, liquid measure, of strong sulphuric acid, to which half a fluid drachm of strong nitric acid is added.

When sulphuric acid only is employed, the sulphate of mercury obtained by evaporation is mixed with two parts of metal, and afterwards with one part and a half of common salt, the whole being triturated in a mortar till the metal disappears. The mass is then sublimed in the usual way. In this operation the whole of the mercury is, however, never reduced to calomel, and on this account the sublimed mass requires purification from corrosive sublimate by repeated washings with boiling water, in which the latter is freely soluble. As soon as the washings give but faint indications of precipitates with a solution of nitrate of silver or sulphide of hydrogen gas, the calomel may be considered pure.

Fig. 366 is a drawing of a subliming apparatus described by MOHR. It consists of an earthenware tube, *b*, one foot long and a little more than two inches wide. This tube passes through a small furnace, and is connected on the left with a small bellows, and on the right with the wider pipe, *c*, that enters the box or chamber, *d*, where the sublimed calomel collects. This box is lined interiorly with glazed paper, the top being secured by a cloth, *m*, which is retained in its place by the funnel-cap, *e*, terminating in the chimney, *f*. At *g* is shown a small iron gallery for retaining hot charcoal, by which means a continuous draught is maintained.

The fire having been laid on at *a* and *g*, and as soon as the temperature rises to the subliming degree, air is urged through the apparatus by working the bellows, and this forces the calomel vapors, as fast as they rise, into the chamber, *d;* as soon, however, as the chimney has become sufficiently hot by the chauffer in it, the blowing apparatus may be detached, as there will then be sufficient draught to carry the sublimed vapors into the receiver without mechanical aid. As the charge already in the tube, *b*, becomes exhausted, a further quantity may be introduced at the open side, and as long as the fire in *g* remains, the current of air drawn through will be sufficient to prevent any mercurial vapor escaping by the open end.

Fig. 366.



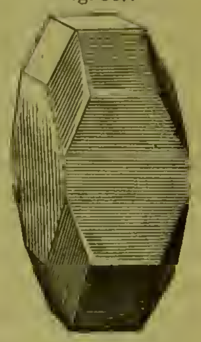
Under ordinary circumstances the incrusted calomel requires to be finely ground before it is fit for use. This operation is generally performed under lead rollers, unless the salt be minutely subdivided at the moment of condensation. Mr. **Jewell**, patented a process for effecting this, which has since been improved by M. O. **Henry** and **Soubeiran**, and consisted in allowing the mercurial vapor to pass into a vessel charged with steam, having water in the bottom. By this arrangement the substance becomes reduced to the finest state of division.

Thomson's Gaseous Method.—A patent was sealed on the 8th March, 1841, by Dr. **Anthony Todd Thomson**, for manufacturing the chlorides of mercury by the direct union of the elements. It has long been known that even at common temperatures mercury and chlorine gas combine, though slowly, and that when heated the combination is effected rapidly with the development of heat and light. In Dr. **Thomson's** process the proportion in which the gas is admitted determines the nature of the product. The process is as follows:—A glass, earthenware, or other suitable vessel, provided with openings at both ends, is mounted in brickwork, or in any other convenient manner, and exposed to the action of an open fire beneath. A certain quantity of mercury is placed in this vessel, and the temperature raised to between 350° and 660°. One end of the glass communicates with an alembic, such as is generally used for generating chlorine gas, and the other end is connected with a large chamber made perfectly air-tight, to prevent the escape of any of the gases. In order to procure the chlorine, the alembic is charged with a mixture of common salt, binoxide of manganese, and sulphuric acid. The chlorine gas, as it is generated, passes from the alembic through the bent tube into the glass or earthenware vessel which contains the mercury, when it combines with its vapors, generated by raising it to 350° and above. The combination of the two gases forms either calomel or corrosive sublimate according to the quantity of chlorine gas employed. The product is found at the bottom of the air-tight vessel, from whence it may be taken after the operation is completed.

The patentee claimed the direct combination of the gas, not only with the mercurial vapor, but with the metal in any form.

Properties of Calomel.—The form in which calomel sublimes is modified by the dimensions of the apparatus employed, and the temperature at which it is produced. Prepared in small vessels it usually takes the shape of a fibro-crystalline cake, which when powdered is yellow or buff, whereas if the apparatus is large, and the receiver cold, it falls as a white impalpable powder. The crystals of calomel are square prisms, Fig. 367, with a specific gravity of 7·150; 7·156, **Pelouze** and **Fremy**; 6·9920, **Karsten**. Calomel is not volatile at ordinary temperatures. Below a red heat it sublimes without fusing. It has neither taste nor smell, and is insoluble in pure water at 60° Fahr. Boiling muriatic acid quickly changes calomel into corrosive sublimate and metallic mercury. In hot nitric acid it dissolves, evolving nitric oxide. In the cold, sulphuric acid neither dissolves nor decomposes it, but the action of hot sulphuric acid is to produce the higher chloride, a sulphate of mercuric oxide, and sulphurous acid gas, thus—

Fig. 367.



$$\underbrace{Hg_2\,Cl}_{\text{Subchloride of mercury.}} + \underbrace{2\,SO_3}_{\text{Sulphuric acid.}} = \underbrace{Hg\,Cl}_{\text{Chloride of mercury.}} + \underbrace{HgO\,SO_3}_{\text{Sulphate of mercury.}} + \underbrace{SO_2}_{\text{Sulphurous acid.}}$$

Solutions of the fixed alkalies convert it into black oxide, and by ammonia it is changed into the double salt, $2\,(Mg\,NH_2), Hg_2\,Cl$, which is also black. This amide compound is different from that which is formed when calomel and dry ammonia are brought in contact; the last has, according to **Kane**, the formula $2\,Hg_2\,Cl, H\,NH_2$.

The trade adulterations of calomel are chalk, sulphate of baryta, carbonate of lead, common salt, sal ammoniac, and sometimes a little corrosive sublimate. For the detection of all impurities, the Edinburgh college directs that heat, sulphuric ether, and solution of caustic potassa should be employed. Calomel, if pure, is entirely volatilized by heat, all fixed impurities will therefore be found in the residue, whilst the sublimate may contain, besides calomel, the mercuric chloride and sal ammoniac. These impurities being soluble in water, a solution is readily obtained containing both, and this liquid, when acted on by aqua potassæ, gives a yellow precipitate or cloud; after which, if gently heated, fumes of ammonia will be given off, producing, in contact with muriatic acid, the white vapors of muriate of ammonia. Or the liquid may be gently evaporated, and the solid residue treated with solution of caustic potassa, after which the volatile ammonia may also be brought in contact with the hydrochloric acid vapor.

The fixed residue supposed to contain barytic, sulphate, white lead, and chalk, may now be treated with pure and dilute nitric acid; any insoluble matter still remaining is set aside for examination, and the solution in nitric acid, which, if it was attended with effervescence, showed the presence of carbonic acid, may be, if necessary, diluted with water. Solution of sulphide of hydrogen gas is then added, and a black precipitate obtained, if lead be present. The clear liquid filtered from the plumbic sulphide is next neutralized by ammonia, and oxalate of ammonia added. A white precipitate proves the presence of lime.

Returning now to the insoluble residue from the nitric solution, which may still contain sulphate of lead and sulphate of baryta—the solid matter may at once be tested with a drop of sulphide of ammonium. If lead be present, it will be immediately blackened. If otherwise, then having been well washed with water, it may be boiled with pure carbonate of potassa, the solution filtered, excess of alkaline carbonate in the liquid expelled by pure hydrochloric acid, and afterwards chloride of barium added to detect the presence of sulphuric acid. If a white precipitate is observed, then the white matter left on the filter is carefully washed and dissolved in a small portion of pure hydrochloric acid; to this liquid dilute sulphuric acid is next added, and a precipitate of sulphate of baryta is obtained.

It is well known that calomel boiled with water, very slightly acidulated with hydrochloric acid, and containing a slip of clean copper, gives a deposit on that metal of metallic mercury. In the case of a solution of corrosive sublimate, the same test may be employed, or the following neat arrangement may be adopted:—A drop of the liquid is placed on a sovereign, and an iron key is placed so that one part is immersed in the liquid whilst another touches the gold of the coin. At the former point a brilliant mercurial stain is immediately produced by the galvanic current. A copper coin may take the place of the gold, in which case a strip of clean zinc, slightly arched, must be substituted for the iron key.

Finally, it being established that the solution contains mercury, the identification of it, as the bichloride, may be easily effected by solutions of nitrate of silver, caustic ammonia, iodide of potassium, and protochloride of tin.

Medicinally, calomel is the mildest and most generally employed of all mercurials. It is irritant, however, in large doses, and to some constitutions, violently so. In small doses, and especially when combined with opium, it is sedative and antiphlogistic. Even alone, it possesses a cathartic action; but this, like the preceding, is rendered more certain by combining it with evacuants, as jalap and colocynth. Combined with digitalis or squills it is an effective diuretic, and its diaphoretic, like its sedative properties, are best developed in combination with opium. Its alterative properties are most generally produced by the use of small doses daily, or it may be given along with the golden sulphide of antimony, as *Plummer's pill.*

The Editor trusts, however, that before many years are over, medical men will have abolished the administration of all hydrargic compounds, which can only have a baneful effect upon the system.

Protochloride of Mercury.—Corrosive Sublimate.—This combination of mercury, though containing the same elements as the last described compound, has very different properties, and, in a medical point of view, is much more active. It has been known from time immemorial, though the first description of it was given by GEBER of Thus, in Persia, who lived in the ninth century; and it has occupied ever since a prominent place in the *materia medica* of succeeding physicians. It may be prepared by acting upon the sulphate of protoxide of mercury by various metallic chlorides in solution—chloride of barium for instance—when a chloride of mercury is produced, together with a sulphate of the base of the precipitant. If the latter be insoluble, as in the case of baryta, the mercurial chloride may be obtained by evaporating the filtered liquor to dryness. Alkaline chlorides, chloride of magnesium, and other similar salts, effect the same changes, but slowly. By bringing together the vapor of mercury and chlorine gas, in the equivalent proportions, it is likewise produced.

None of these methods are, however, followed in its manufacture, recourse being always had to the dry process of subliming a mixture of chloride of sodium and sulphate of mercury, when a chloride of the latter and sulphate of soda are formed, the mercurial compound being expelled by the heat. Thus:—

$$\underbrace{\mathrm{Hg\,O\;SO_3}}_{\text{Sulphate of mercury.}} + \underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} = \underbrace{\mathrm{Hg\,Cl}}_{\text{Chloride of mercury.}} + \underbrace{\mathrm{Na\,O\;SO_3}}_{\text{Sulphate of soda}}$$

Considerable quantities of this compound were prepared by the Dutch manufacturers before the knowledge of its formation became more general. Their mode of procedure was to mix equal parts of nitrate of mercury, decrepitated salt—chloride of sodium—and calcined or white martial vitriol—subsulphate of the sesquioxide of iron—and introduce the composition into a matrass, filling only one-third its capacity. The vessel was then imbedded in the sand bath, and heat applied till its bottom assumed a dull red, when a series of decompositions took place, by which chloride of mercury was produced and sublimed, whilst sulphate of soda and sesquioxide of iron remained in the matrass, and the nitric acid, after suffering decomposition, was evolved as nitrous acid, quadroxide of nitrogen—NO_4—and oxygen. Another process was to cause metallic mercury, chloride of sodium, saltpetre, nitrate of potassa, and martial vitriol to react upon one another in the matrass by heat, when corrosive sublimate resulted.

Gmelin gives the rationale of this operation in the formula—

$$\underbrace{Hg}_{\text{Mercury.}} + \underbrace{Na\ Cl}_{\text{Chloride of sodium.}} + \underbrace{KO,\ NO_5}_{\text{Nitrate of potassa.}} + \underbrace{Fe_2\ O_3,\ 2\ SO_3}_{\text{Basic sesquisulphate of iron.}} = \underbrace{Hg\ Cl}_{\text{Chloride of mercury.}} + \underbrace{Na\ O\ SO_3}_{\text{Sulphate of soda.}} + \underbrace{KO\ SO_3}_{\text{Sulphate of potassa.}} + \underbrace{Fe_2\ O_3}_{\text{Sesquioxide of iron.}} + \underbrace{NO_4}_{\text{Peroxide of nitrogen.}}$$

Kunkel improved upon the process by producing first a sulphate of the protoxide of mercury, by acting on the metal with oil of vitriol, and heating in a matrass equal parts of this and common salt. Subsequently, **Fourcroy**, in order to dispense with the first operation, directed to employ sulphuric acid, mercury, and common salt, to submit the mass to heat, and finally to sublime it. In practice, the proportions taken were ten parts of mercury, eight of common salt, eleven of sulphuric acid, six of peroxide of manganese, and three of water. The decomposition in this case may be represented thus—

$$\underbrace{Hg}_{\text{Mercury.}} + \underbrace{Na\ Cl}_{\text{Chloride of sodium.}} + \underbrace{HO\ SO_3}_{\text{Sulphuric acid.}} + \underbrace{Mn\ O_2}_{\text{Binoxide of manganese.}} = \underbrace{Hg\ Cl}_{\text{Chloride of mercury.}} + \underbrace{Na\ O\ SO_3}_{\text{Sulphate of soda.}} + \underbrace{HO}_{\text{Water.}} + \underbrace{Mn\ O}_{\text{Protoxide of manganese.}}$$

That is, there is formed, in the first instance, a sulphate of mercury by the concurrent oxidation of the binoxide of manganese and the action of the sulphuric acid, and this sulphate is afterwards decomposed in the heat by the salt chloride of mercury being formed and expelled to the upper part of the mattrass; sulphate of soda and protoxide of manganese being left in the bottom of the vessel.

The London college directs that one pound of mercury be boiled with thirty-one fluid ounces of sulphuric acid, and that the dry bipersulphate is to be mixed with half a pound of salt, and sublimed.

In the receipt of the Edinburgh college, the process for preparing calomel and corrosive sublimate is the same, with the exception that only half the quantity of mercury is taken for the latter.

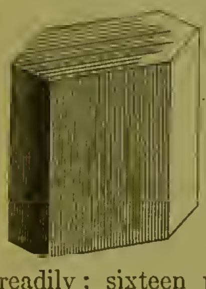
The Dublin college at first prepares the sulphate of mercury, and intimately mixes this in fine powder with dried common salt, likewise ground, in the proportion of two of the former to one of the latter, subjecting the mixture to heat in an iron pot lined with clay, to which an earthen head is adapted. In either of these operations the temperature at which the salt is sublimed should not be too elevated, as in this case the chloride would fuse and fall back into the vessel, and thus occasion a loss.

In the formation of the sulphate of mercury, preparatory to subliming it with common salt, the materials are introduced into a cast-iron boiler, placed in brickwork, having a fire beneath it, and surmounted by a hood, to carry off the noxious gas evolved into the chimney. The heat required to effect the union of the mercury with the acid is moderate. In the course of the action, one portion of the acid is decomposed into oxygen, and sulphurous acid, which escapes; the oxygen unites with the metal, and the oxide so formed, is salified by a second equivalent of sulphuric acid; the mass forms a thick magma, and continues to evolve sulphurous acid as long as any metal remains unoxidised. Some subsulphate is apt to be produced; but as it is necessary for the purity of the chloride which is intended to be obtained from this, to have the whole of the metal in the state of protosulphate, a quantity of acid should be employed at the end of the process, before the drying of the salt. The better to insure this, several tests may be made with a portion of the sulphate from time to time, by suspending it in water saturated with chloride of sodium; when the whole dissolves, it is evident that all the mercury is in the form of protosulphate; but should a white deposit be formed, it indicates that a sulphate of the suboxide still remains. When the sulphate is prepared, it is mixed with the requisite quantity of alkaline chloride, and a little binoxide of manganese—one part to ten of the mercuric sulphate operated upon—and allowed to remain during two or three days, with the view of effecting a thorough decomposition. At the expiration of this period the fire is lighted, and a gentle heat maintained till all moisture has evaporated; after which, the mass is put into the sublimers, which may be of green glass, resting on cast-iron plates, and imbedded in sand up to the neck. In large factories, the subliming furnace is usually an oblong, capable of holding about one hundred matrasses, and heated by fires symmetrically disposed along the longer side. These are generally covered by a prismatic conical hood, from which a pipe leads into the chimney, with the view of carrying off any escaping vapors of the mercurial compound, and for which use, to be effectual, the chimney should have a good draught. The most important part of the business is the regulation of the heat, which, in the first instance, disengages moisture, and after this the mercurial salt begins to be volatilized. At this stage a small glazed conical vase is inverted on the neck of each matrass, in order to arrest any vapors which may make their escape. When white vapors are observed, it is a certain sign that the heat is too strong, in which case the vessel must be cooled by removing a portion of the sand from its upper part. Towards the end of the sublimation the blast must be increased, with the view of bringing the sublimed chloride nearly to its fusing point, for the purpose of causing it to adhere together in a compact cake; but for reasons already assigned, the temperature must not be carried too far, since this would occasion a loss. After the sublimation the fire is withdrawn; and as soon as the sand has sufficiently cooled, the matrasses are taken out and broken in the middle as gently as possible, so as not to detach the crust of salt upon the upper part. Finally, the fragments of glass and discolored parts are removed, and the pure cakes set aside to be ground and packed.

Any subchloride of mercury which may happen to be formed during the sublimation, owing to its not being so volatile as corrosive sublimate, forms a whitish ring on the lower part of the sublimed crust, and thus admits of being removed. Such portions may be added in the succeeding charge which is being converted into sulphate, and afterwards re-sublimed.

Properties.—Ordinary sublimed chloride of mercury is a white satiny substance having a crystalline appearance, although often no distinct order can be distinguished. If, however, the sublimation be effected at a low heat, and as slowly as possible, crystals appear, having the shape of flattened tetrahedral prisms, Fig. 368, with a specific gravity of 5·4. The sublimed salt appears more or less translucent, and when in thin fragments often transparent. In the heat it is very volatile, entering first into fusion before it is disseminated. According to FARADAY, the salt volatilizes at ordinary temperatures, but REIGEL found this not to be the case. Water dissolves it very readily; sixteen parts are required in the cold, but three parts at 212° are sufficient to dissolve one part of it, and the liquid reacts acid to test-paper. A hot, concentrated, aqueous solution of mercurial chloride deposits crystals on cooling, which slightly differ in appearance from those obtained by sublimation: they are anhydrous. Alcohol and ether also take it up very freely; seven parts of cold alcohol dissolve three of corrosive sublimate, but the same quantity at a boiling temperature takes up six parts of the salt. When sulphuric ether is added to a solution of corrosive sublimate in water, the mobile liquid abstracts the salt, and an ethereal solution of chloride of mercury floats on the water, which is more or less reduced of its saline constituent. Acids aid in the solution of this body in water, without, however, causing any decomposition or alteration of it. Hydrochloric acid converts it, however, into a hydrochloride of chloride of mercury; sulphide of hydrogen in excess gives rise to a black protosulphide of mercury, but if this agent be sparingly added, a compound of sulphide and chloride of mercury is produced. Potassa in excess throws down the protoxide, but if the solution be not saturated with the alkali, a white oxychlorido separates. Ammonia gives rise, also, to an amidochloride of mercury, which an excess of ammonia dissolves. A solution of iodide of potassium throws down a scarlet precipitate of iodide of mercury. Protochloride of tin causes at first a reduction to the subchloride of mercury, which precipitates; but this also becomes reduced to the metallic state, hydrochloric acid being set free in the liquid. By exposure to sunlight an aqueous solution of the salt suffers decomposition into calomel, hydrochloric acid, and oxygen, thus:—

Fig. 368.



$$2\,\mathrm{Hg\,Cl} + \mathrm{HO} = \mathrm{Hg_2\,Cl} + \mathrm{HCl} + \mathrm{O}$$

It is likewise decomposed by various substances, metallic, non-metallic, and organic; the latter usually converting it to the state of subchloride. It forms insoluble, or at least but very partially soluble precipitates with albumen and fibrin.

The centesimal composition of protochloride of mercury corresponds with the chemical formula Hg Cl, as shown in the annexed:—

	At Weight.	Centesimally. Theory.
1 Eq. of mercury,	100	73·86
1 Eq. of chloride,	35·5	26·14
1 Eq. of chloride of mercury,	135·5	100·00

	Vol.	Specific Gravity.
Vapour of mercury.	1	6·9300
Chlorine gas,	1	2·4543
Vapour of chloride of mercury,	1	6·3843

On all animals the effects of chloride of mercury are, as its technical name implies, those of a corrosive poison, and by its external application even, it has proved fatal to man. When swallowed in any quantity, the symptoms come on almost immediately. Indeed, the rapidity of their appearance and the strong metallic taste which is experienced, are among the phenomena which strongly distinguish cases of poisoning by this agent from those occasioned by arsenic. According to WRIGHT, the best antidote against its poisonous action is the white of egg suspended in water and milk—one egg is said to be required for every *four grains* of the poison; hydrated sesquioxide of iron has also been recommended, and likewise, on account of the gluten it contains, wheat-flour and water. In this country it is little employed internally for allaying human maladies; and even its external application is not free from danger. In veterinary practice, however, it is frequently used, especially in the form of ointment or wash.

The salt has been extensively employed for the preservation of subjects of natural history, and likewise for preserving wood against the dry rot.

Compound Chlorides of Mercury.—Corrosive sublimate is capable of entering into combination with hydrochloric acid and most of the metallic chlorides, forming well-defined crystallizable salts. Thus, with hydrochloric acid it produces a compound, expressed by Hg Cl, HCl or Hg Cl$_2$, HO; with chloride of potassium, Hg Cl, KCl, 2 HO, 2 Hg Cl, KCl, 4 HO, and 4 Hg Cl, KCl, 8 HO$_2$. Soda, lithia, baryta, strontia, calcia, and magnesia salts react in the same way, as also the chlorides of manganese, iron, nickel, and cobalt, all of which produce with the mercurial salt well-defined crystalline compounds.

The same compound, when cautiously treated with a dilute solution of a fixed caustic alkali, or with one of the carbonates of the alkalies, gives rise to a compound of chloride and oxide of mercury, having the composition Hg Cl, 3 Hg O—a chloride of the alkali in the first case, and a bicarbonate in the second instance, being formed. All these, however, though interesting to the theoretical chemist, are as yet of no practical utility, and therefore will not be discussed here at greater length. At the same time there is one combination which arises from the addition of ammonia to a solution of chloride of mercury, that has many valuable properties in medicine, and on that account merits a short description, namely:—

Amido-Chloride of Mercury—White Precipitate.—This compound is obtained by adding to a solution of two equivalents of the chloride of mercury—271 parts—in a large quantity of water, a solution of ammonia as long as a precipitate is formed, collecting the separated substance, washing with cold water, and drying.

For a long time this body was thought to be identical with calomel, till Rammelsberg showed it to be different, and Kane demonstrated its true composition, in his researches on the *Amides*. The reactions in its formation may be expressed thus :—

$$2\,Hg\,Cl + 2\,NH_4\,O = Hg\,Cl\,Hg\,NH_2 + NH_4\,Cl + 2\,HO$$

That is to say, one equivalent of the volatile alkali suffers decomposition into amidogen—NH_2—water and hydrogen; the amidogen takes an equivalent of the mercury from the corrosive sublimate and sets free chlorine, which seizes on the ammonium of the second equivalent of the alkali, and forms chloride of ammonium, thus liberating its oxygen to the hydrogen set free in the first change.

Amido-chloride of mercury forms a snow-white mass, without odor, but possessing a nauseous metallic taste. It requires for solution about six hundred parts of water, but the mineral acids readily dissolve it. When heated it volatilizes without fusing, but Wittstein states that the same compound, when obtained from chloride of mercury, chloride of ammonium, and a fixed alkaline carbonate, melts in the heat before dissipation. In either case the compound is completely broken up into corrosive sublimate, ammoniacal gas, and nitrogen, as shown by the equation :—

$$3\,(Hg\,Cl,\,N\,H_2\,Hg) = 3\,Hg_2\,Cl + 2\,N\,H_3 + N.$$

When the precipitate is boiled in water, chloride of ammonium is produced, and a heavy yellow powder composed of two equivalents of protoxide of mercury, one of protochloride, and one of amide of mercury falls. Potassa likewise changes it into oxide and chloride of the metal, ammonia being evolved. Caustic ammonia has no apparent action, and hence this alkali serves to distinguish it from calomel, which is turned grey or blackish by it. Its composition is given :—

		Centesimally.	
	At weight.	Theory.	Kane.
2 Eqs. of mercury, ...	200·0	79·522	78·60
1 Eq. of chlorine,.......	35·5	14·115	13·85
1 Eq. of nitrogen,......	14·0	5·566	6·37
2 Eqs. of hydrogen, ...	2·0	0·795	
Water,................	—	—	0·58
	251·5	99·998	99·40

Or,

	At. weight.	Centesimally. Theory.
1 Eq. of chloride of mercury,....	135·5	53·876
1 Eq. of amide of mercury,......	116·0	46·124
	251·5	100·000

This compound, in a physiological point of view, has been but imperfectly studied. It is, however, regarded as an energetic poison, in this exhibiting a similarity with corrosive sublimate. It is never administered internally, but may be used externally in the form of an ointment, and is efficacious in various skin diseases. In cases of poisoning with this substance, albuminous antidotes, such as are given to reduce the action of corrosive sublimate, serve best. It is said that white precipitate is much adulterated with sulphate of lime, carbonate of lime, and carbonate of lead. The extent of the adulteration may readily be found by heating a weighed quantity, and weighing the residue should any be left.

Iodide of Mercury.—Iodine and mercury are capable of entering into several states of combination; and some of the compounds so formed are capable of constituting binary salts with the alkaline iodides. Thus, there is the green iodide of mercury, $Hg_2\,I$; the yellow iodide, $Hg_3\,I_2 = Hg_2\,I,\ Hg\,I$, and the red iodide, $Hg\,I$. The latter compound produces, with iodide of potassium, a mono- bi- and tri-iodrargyrate of potassium, the composition of which respectively is $Hg\,I, K\,I$; $2\,Hg\,I,\ K\,I,\ 6\,HO$, and $3\,Hg\,I,\ K\,I$. There are formed similar compounds from the iodide of mercury and the soluble chlorides, but as objects of manufacture, they are of no interest. Respecting the manufacture of the scarlet iodide of mercury, the reader will find particulars under iodine at page 398.

Fulminate of Mercury.—*Fulminating Mercury; Mercure fulminante*, French; *knallquecksilber*, German.—This very explosive compound was first described by Howard in the Philosophical Transactions for 1800. Brande gives the following method for its preparation:—One hundred grains of mercury are treated with an ounce and a half by measure of nitric acid, aided by heat in a porcelain basin, till the whole is dissolved. As soon as the liquid is cold, two ounces by measure of alcohol, specific gravity ·85, are added, and a gentle heat applied. Brisk action takes place, ethereal vapors being copiously evolved, and a yellow-grey precipitate deposited, which is the compound in question. If the effervescence be too brisk, the vessel should be withdrawn from the heat, and its contents cooled by the addition of more alcohol. As soon as the precipitate has formed, it is to be well washed by decantation and filtration, only a small quantity of distilled water being used in the latter process. The temperature at which the compound is dried should not exceed 100°, and only small quantities ought to be operated upon at a time to guard against an explosion. One hundred and twenty grains of the fulminate are obtained from the above quantity of mercury when the operations are successfully conducted. It happens that on the addition of the alcohol, a portion of the mercuric salt is reduced to the state of metal, but this can be separated from the yellowish salt after the spirit is decanted by treating with boiling water, in which the fulminate is soluble; and by filtering off the liquor and setting it aside to cool, the salt separates in silky acicular crystals. When it is required to prepare it in large quantities, the course followed is to dissolve one part of mercury in twelve of nitric acid of 1·36 specific gravity, and to add eleven parts of alcohol, specific gravity ·850, when the solution is cold. On slightly heating the vessel, brisk action takes place as above stated, and similar effects are produced. The separated metal is removed from the explosive compound by boiling water, from which the fulminate is deposited on cooling in silky crystals. Cremascoli directs, as the safest method, to treat half an ounce of the metal with six ounces of nitric acid of 1·30 in a flask, which should be held in boiling water for a minute or so, and as soon as solution takes place, and the temperature is reduced to 55°, to pour in four ounces of alcohol of ·833 specific gravity, and again to immerse the flask in boiling water for two or three minutes, till dense white vapors begin to fill the upper part of the vessel, at which period it should be removed from the heat. The reaction is said to be very moderate in this instance, and the whole of the fulminate falls down in the course of a few hours, when it may be purified by decantation and washing.

Fulminate of mercury forms an extremely dangerous substance to operate upon, owing to the readiness with which it explodes, the violence of which has repeatedly been the cause of serious injury, and even of loss of life. It detonates strongly when struck with a hard body; but sometimes trifling friction may serve to produce this effect, even when in a moist state. Heated to 300° it explodes, and at the same time evolves a bright flame; the electric spark, and contact with strong nitric and sulphuric acids, also induce its decomposition, which is invariably accompanied with explosion. The products resulting from it, when detonated, are carbonic acid, nitrogen, and vapor of mercury. Its chemical formula is expressed by $2\ HgO,\ C_4\ N_2\ O_2$, or $2\ HgO,\ Cy_2\ O_2$, that is, two equivalents of protoxide of mercury and one of fulminic acid.

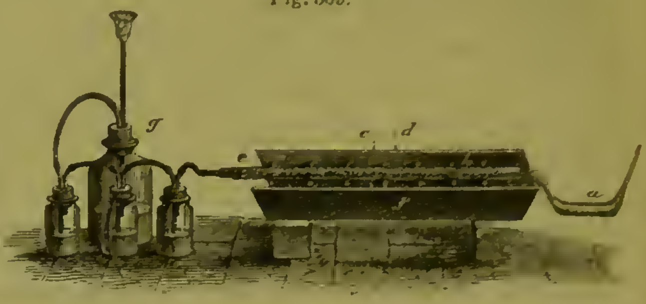
Fulminating mercury has been much used since its discovery for the manufacture of percussion caps for guns, and latterly has been employed in the construction of destructive machines, such as grenades and the like. HOWARD endeavoured to substitute it for gunpowder, but was unsuccessful, owing to the nature of its explosion, which is such as to destroy the gun by its suddenness and force without expelling the shot. When used for priming percussion caps it may be moistened with a little resinous tincture, and dropped into the little capsule, but the universal practice is to mix it with about six per cent. of nitrate of potassa and water, sufficient to reduce the whole to a thin paste. A small quantity of this is dropped into each cap, and carefully dried at a low heat.

Analysis of Mercurial Matters.—Already a short description of the method of analysis pursued in determining the richness of mercurial ores has been given, and although the system of analysis to which reference will now be made is analogous to that described, still, since it is more applicable to mercurial compounds in general, it deserves a short space here. It is known as MILLON's method, and is conducted as follows:—

A hard German glass tube, such as is generally employed in organic analysis, is taken and drawn out in the form represented by *a*, *b*, *c*, in Fig. 369.

The part *a* is intended for the retention of the reduced mercury, and the rest, from *b* to *c*, for the reduction of the ore or salt of mercury. A plug of asbestos is introduced into the end, *b*, and then fragments of quicklime as far as *d*; the compound to be analysed, in quantities varying from fifteen to twenty grains, is then carefully put in, and fills from *c* to *d*, and fragments of quicklime are made to occupy the rest of the tube to *c*. When nitric acid exists in the compound to be analysed, copper turnings are substituted for the quicklime in the part *b d*. The extremity, *c*, is connected by perforated corks, quill tubes, and flexible connectors, with the apparatus, *g*, for generating a current of pure dry hydrogen gas. The charged tube being placed in the combustion furnace, *f*, and connected with the apparatus, *g*, and filled with gas, ignited charcoal is placed round the part from *b* to *c*, and as soon as this is red-hot the remainder is gradually heated to redness to the end, the current of gas being still maintained. During this operation the mercury is disengaged, and collects in the part, *a*, the water which is generated or contained in the substance being carried off by the current of hydrogen. When the operation is over, the narrow neck near *b* is cut off, and the part containing the reduced metal weighed; after this, the metal is taken out, and any portions remaining dissolved with nitric acid, then washed with distilled water, dried and reweighed. The difference of the two results will be the weight of metal in the sample operated upon.

Fig. 369.



Provided no easily reduced metal be contained in the substance to be assayed, a quicker method may be resorted to. It consists in adding to the solution of the compound, as free from nitric acid as possible, protochloride of tin, acidulated with hydrochloric acid, and collecting the precipitated mercury on a weighed filter, washing and drying under the exhausted receiver, over sulphuric acid, and weighing.

To Dr. DALZELL, of Edinburgh, the Editor feels indebted for much of the valuable matter contained in this article, and kindly supplied gratuitously and unsolicited.

NICKEL.—English, French, and German.—It was CRONSTEDT who, in 1751, showed that nickel was a distinct body. MILLER remarks that it always occurs in nature associated with iron, both as a constituent of meteoric iron, and in the ores of that metal, which present a composition analogous to those of cobalt. Nickel may be obtained pure upon a small scale by dissolving the roasted ore in aqua regia, evaporating to expel the excess of acid, redissolving in water, and transmitting through the menstruum a current of sulphide of hydrogen. The filtrate is boiled with nitric acid, to sesquioxidize the iron; the solution is precipitated by an excess of ammonia, filtered from the ferruginous oxide, and to the blue liquid potassa is added until the azure tint entirely disappears. A pale-green precipitate, consisting of hydrated oxide of nickel and potassa, is thus obtained, which must be well washed with hot water to remove the alkali, and then reduced by ignition in a current of hydrogen gas. If heated for an hour by means of a blacksmith's forge, in a crucible lined with charcoal, a well-fused button of carbide of nickel is produced; a globule of the pure metal may, however, be procured by heating the oxalate of nickel intensely in a crucible with a luted cover, without any other reducing agent than the carbonic oxide furnished by the decomposition of the vegetal acid.

Pure nickel is a brilliant, silver white, ductile metal, little more fusible than iron. At ordinary temperatures it is susceptible of magnetism, but it loses this property almost entirely if heated to a point exceeding 630°, though it recovers its magnetic power on cooling. Nickel becomes oxidized by exposure to a current of air at an elevated heat. The metal is easily attacked by nitric acid and aqua regia, and is dissolved slowly, with evolution of hydrogen, in sulphuric or in hydrochloric acid. Its specific gravity is 8·82; its symbol Ni; and its equivalent 29·5.

SOURCES.—Native nickel occurs at Westerwald in the Erzegebirge, in Bohemia, combined with arsenic, under the significant name of *kupfernickel;* with cobalt, iron, and copper, as *arsenic-nickel*, in the Hartz; at Riechelsdorf in Hessia, as an oxide, in *nickelschwartze;* as a sulphide in *haarkies;* as a sulphide and arseniate of nickel in *nickelglanz;* and with sulphur and antimony in *nickelspeisglanzerz*, at Siegen, and near Freussberg, in the principality of Nassau. Nickel is always present in meteoric stones. Kupfernickel occurs in numerous external shapes; as uniform, globular, botryoidal, arborescent, massive, and disseminated; fracture, coarse or fine grey; in silver and cobalt veins, in gneiss, sienite, mica-slate, kupfershiefer, accompanied by speiss cobalt, native silver, quartz, *et cetera.* It is found in Westphalia near Ospe, in Hessia at Riechelsdorf, and Biber in Baden; in the Saxon Erzegebirge, near Schneeberg and Freiberg; in Bohemia, at Joachimsthal; in Thuringia, at Saalfield; in Steyermark, near Schladming; in Hungary, France, and England.—*Ure.*

Subjoined are the analyses and characteristic properties of a few of the more important of these minerals:—

Kupfernickel.—The composition of this mineral, as stated by STROMEYER and PFAFF, is as follows:—

	Centesimally.	
		Riegelsdorf.
Nickel,	44·20	48·90
Arsenic,	54·70	48·70
Iron,	0·33	0·44
Lead,	0·32	0·96
Sulphur,	0·45	0·90
Loss,	—	0·10
	100·00	100·00

It is of a copper or yellowish-red hue, but acquires a grey or blackish tarnish by exposure. The specific gravity is 6·6—7·6. It occurs reticulated, dendritic, and botryoidal, but more commonly massive; never crystallized; streak, pale brownish-black. The fracture is imperfectly conchoidal, or fine-grained and uneven, with a glistening or shining metallic lustre; it yields to the knife with difficulty, and is brittle. Before the blowpipe it gives out an arsenical vapor, and then fuses, though not very easily, into a white metallic globule. After roasting, it usually tinges a bead of borax blue, indicating the presence of a certain quantity of cobalt. In nitric acid it assumes a green coating, and in aqua regia is dissolved.

Haarkies—Sulphide of Nickel.—The following is ARFEDSON'S analysis:—

	Centesimally.	
Nickel,	64·76	65·74
Sulphur,	35·24	34·26
	100·00	100·00

With traces of cobalt and arsenic. Its specific gravity is 6·45.

It occurs in capillary and sometimes diverging filaments of a yellowish color, inclining to steel-grey. Primary form the cube; flexible; opaque, with a metallic lustre; not magnetic. Before the blowpipe on charcoal, with a good heat, it fuses into a globule which is metallic, malleable, and magnetic, and consists wholly of nickel; but in the open tube it exhales the smell of sulphurous acid. With nitric acid it forms a greenish solution.

Nickelspeisglanzerz.—This mineral is generally a combination of nickel, sulphur, and antimony, in the following proportions:—

	Centesimally.
Nickel,	27·36
Sulphur,	16·98
Antimony,	55·66
	100·00

Its specific gravity is 6·45—6·5, and its primary form a cube. It occurs in masses, which have a granular composition, and possess a steel-grey or silver-white color; lustre, metallic; cleavage, perfect parallel to the faces of the cube; brittle. Before the blowpipe it is partly volatilized, disengaging vapors of antimony and sometimes of arsenic, and ultimately melts into a metallic globule, which communicates a blue tinge to glass of borax. It is acted upon by nitric acid, forming an immediate precipitate, and imparting to the solution a greenish tinge.

Meteoric Stones.—A natural alloy of nickel and iron, forms a principal metallic ingredient in most *aërolites*, or *meteoric stones.* Though nothing is really known of the source or origin of these bodies, remarks BRANDE, it has been ascertained upon satisfactory evidence, that they are not of terrestial formation; and, consequently, their visits to the surface of this planet have awakened much speculation, and some experimental research. The first tolerably accurate narration of the fall of a meteoric stone relates to that of Ensisheim, near Basle, upon the Rhine, which fell in 1492, and weighed two hundred and fifty-five pounds. The account which is deposited in the church, runs thus:—Anno Domini 1492, Wednesday, November seventh, there was a loud clap of thunder, and a child saw a stone fall from heaven; it stuck into a field of wheat and did no harm, but made a hole there. The noise it made was heard at Lucerne, Villing, and other places. On the Monday, King MAXIMILIAN ordered the stone to be brought to the castle, and having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade anybody to take anything from it. His Excellency, however, took two pieces himself, and sent another to Duke SIGISMUND of Austria.

In 1627, November twenty-seventh, GASSENDI saw a burning stone fall on Mount Vaisir, in Provence; he found it to weigh fifty-nine pounds. In 1672 a stone fell near Verona weighing three hundred pounds. LUCAS, when in Larissa in 1706, describes the falling of a stone with a loud hissing noise, and smelling of sulphur. In September, 1753, DE SALANDE witnessed this phenomenon near Pont de Vesle. In 1768 no less than three stones fell in different parts of France. In 1790 there was a shower of stones near Agen, witnessed by DARCET and several other persons. On the thirteenth December, 1795, a stone fell near Major TOPHAM's house in Yorkshire; it was seen by a ploughman and two other persons, who immediately dug it out of the hole it had buried itself in; it weighed fifty-six pounds.

Various other and equally satisfactory accounts of the same kind are narrated. All concur in describing a luminous meteor, moving through the air in a more or less oblique direction, attended by a hissing noise, and the fall of stony or semimetallic masses in a heated state. There exists, however, evidence of another kind, proving the peculiar origin of these bodies. It is, that although they have fallen in very different countries and at distant periods, when submitted to chemical analysis they agree in component parts; the metallic particles being composed chiefly of iron and nickel, with magnesia and silica.

Large masses of native iron have been found in different parts of the world, of the history and origin of which nothing very accurate is known. Such are the great block of iron formerly at Elbogen in Bohemia; the large mass discovered by PALLAS, weighing sixteen hundred pounds, near Krasnorjark in Siberia; that found by GOLDBERRY in the great desert of Zara in Africa; probably, also, that mentioned by BARROW, on the banks of the great Fish-river in Southern Africa; and those noticed by CELIS, HUMBOLDT, and others, in America, of enormous magnitude, some exceeding thirty tons in weight. That these should be of the same source as the other meteoric stones, seems at first incredible; but when they are submitted to analysis, and the iron they contain found alloyed with nickel, it no longer seems credulous to regard them as of meteoric origin. Nothing of the kind is found in the earth. Two blocks of such iron were, in fact, observed to fall from a meteor at Hradschina, near Agram, in Croatia, in 1751.

To account for these remarkable visitations of metallic and lapideous bodies, a variety of hypotheses have been suggested. Are they merely earthy matter, fused by lightning? Are they the offspring of any terrestrial volcano? These were once favorite notions; there is no instance recorded in which similar bodies have in that way been produced, nor do the lavas of known volcanoes in the least resemble them; to say nothing of the inexplicable projectile force that would be here wanted.—*Brande.*

The notion that these bodies come from volcanoes in the moon is no longer received. The most plausible hypothesis is that of HUMBOLDT, who supposes that meteoric stones are, in fact, small planets continually wandering in myriads through the celestial spaces, but which occasionally come within the earth's attraction, and fall to the ground.

In meteoric iron the proportion of nickel varies considerably. In a specimen from the Arctic region, BRANDE found 3·2 per cent. In that from Siberia, CHILDREN obtained nearly ten per cent. The analysis may be performed by solution in nitro-hydrochloric acid; the iron is thrown down by excess of ammonia in the state of sesquioxide; it is separated by filtration, washed, and dried; and on evaporating the filtrate, and heating its dry residue red-hot, the oxide of nickel is obtained, which should be redissolved in nitric acid, and precipitated by pure potassa, the mixture being boiled for a few seconds; or the nitro-hydrochloric solution may be precipitated by excess of ammonia, and filtered: the sesquioxide of iron remains upon the filter, and the filtrate is an ammoniacal solution of nickel, from which the metal may be precipitated by ferrocyanide of potassium. The following are some further analyses of meteoric iron:—

	Klaproth.		M. de Rivers and Boussingault.			
	Sclavonia	Siberia.	From the Andes.			
Iron,	96·5	98·5	91·51	91·23	91·76	90·76
Nickel	3·5	1·5	8·49	8·21	6·36	7·87
Loss,	—	—	—	0·56	1·88	1·37
	100·0	100·0	100·00	100·00	100·00	100·00

MANUFACTURE.—The nickel of commerce is chiefly obtained from kupfernickel, nickeliferous pyrites, and from the speiss obtained as a secondary product in the treatment of nickeliferous ores of cobalt. The most productive mines of this metal are those of Saxony, Germany, and Norway. The preparation of pure nickel from speiss is conducted in accordance with a method first proposed by WÖHLER. The powdered speiss is roasted, first alone, and afterwards with the addition of powdered charcoal, to effect the separation of its arsenic. The residue obtained by this process is at present mixed with three parts of sulphur, and one part of carbonate of potassa, and then fused in a large earthen crucible. This product is now edulcorated with warm water, by which the arsenic and sulphur associated with potassium are dissolved, while the nickel, in the form of sulphide, remains at the bottom of the vessel in which the operation has been conducted. When, as sometimes happens, from the employment of too high a temperature at the commencement of the roasting, the whole of its arsenic has not been expelled, the operation must be repeated on the residual sulphide thus obtained. As soon as entirely freed from arsenic, the sulphides are well washed with warm water, and then dissolved in sulphuric, to which a small quantity of nitric acid has been added; the precipitation of the lead, copper, and bismuth, which may be present, is determined by a current of sulphide of hydrogen gas, and the metals which still remain in solution are afterwards precipitated by an alkaline carbonate. This deposit, after being well washed, is then treated with an excess of oxalic acid, which forms an insoluble oxalate of iron, and leaves behind an insoluble oxalate of the oxides of cobalt and nickel. These are then dissolved in ammonia, and treated as already described. The oxalate of nickel deposited from this solution is, after being carefully washed to remove any traces of the ammoniacal liquor, ignited in a close crucible, having an aperture in the lid for the escape of the evolved gases.

As the metal itself is now extensively used in alloys, of which German silver is one of the most important, great pains have been taken to procure it in a state of comparative purity, and several processes have been proposed. According to Louyet, the process by which nickel is extracted from speiss at Birmingham, on the large scale, is as follows:—The speiss is first fused with chalk and fluorspar, the metallic mass obtained is reduced to powder, and roasted for twelve hours to expel the arsenic; the residue is then dissolved in hydrochloric acid; the solution is diluted, and the iron sesquioxidized by the cautious addition of chloroxide of calcium—bleaching powder—milk of lime is then carefully added so long as sesquioxide of iron falls, which carries down with it the last portions of arsenic. This precipitate is well washed, and the liquid, which contains all the cobalt and nickel, is treated with a current of sulphide of hydrogen; the sulphides of copper, bismuth, and lead are thus precipitated, and are thoroughly washed. The whole of the nickel and cobalt still remain in the liquid, which is again treated with chloroxide of calcium: the cobalt is thus thrown down as sesquioxide; after which the total quantity of the nickel is separated from the solution in the form of hydrated oxide, by adding milk of lime as long as any precipitate is produced.

For the separation of nickel and cobalt, the method recommended by Liebig is the best. The cobalt and nickel having been freed from all other substances except salts of potassa or soda, are precipitated in the form of hydrated oxides, which, after partial washing from the adhering alkaline salts, are mixed with caustic potassa and a decided excess of hydrocyanic acid; the mixture is then boiled for ten minutes in order to expel the greater part of the excess of hydrocyanic acid, and to convert the oxides into double cyanides of cobalt and nickel. A cobalticyanide of potassium—$K_3\,Co_2\,Cy_6$—is produced at the same time. The formation of the cobalticyanide may be traced as follows:—cyanide of cobalt is first formed, $H\,Cy + Co\,O = Co\,Cy + HO$, and this cyanide of cobalt, by boiling with an excess of cyanide of potassium and hydrocyanic acid, yields cobalticyanide of potassium and free hydrogen, $2\,Co\,Cy + 3\,K\,Cy + H\,Cy = K_3,\ Co_2\,Cy_6 + H$. The double cyanide of nickel and potassium is very simply formed, as with nickel no compound corresponding to the cobalticyanide is obtained; $2\,K\,Cy + Ni\,O = K\,Cy + Ni\,Cy + HO$. If the solution be now boiled with very-finely levigated oxide of mercury, the nickel salt is decomposed, hydrated oxide of nickel is precipitated, and cyanide of mercury is produced:—

$$\underbrace{\text{K Cy}}_{\text{Cyanide of potassa.}} + \underbrace{\text{Ni Cy}}_{\text{Cyanide of nickel.}} + \underbrace{\text{Hg O}}_{\text{Oxide of mercury.}} = \underbrace{\text{K Cy}}_{\text{Cyanide of potassium.}} + \underbrace{\text{Hg Cy}}_{\text{Cyanide of mercury.}} + \underbrace{\text{Ni O}}_{\text{Oxide of nickel.}}$$

The cobalticyanide of potassium is not decomposed by the oxide of mercury, but remains in solution, and may be filtered from the oxide of nickel, which requires to be carefully ignited in a platinum crucible till it ceases to lose weight. The cobalt may then be precipitated from the filtrate as a white subcobalticyanide of mercury, by the addition of solution of subnitrate of mercury; the precipitate is collected, dried, and ignited, when pure oxide of cobalt is left, which may be reduced to the metallic state in a current of hydrogen.

The solution of the oxides, which must be free from nitric acid, is, after previous neutralization of the free acid which may be present, by ammonia, precipitated with sulphide of ammonium, and highly dilute hydrochloric acid, according to Rosé, or acetic acid—Wackenroder—is then added. This serves to dissolve the sulphide of manganese and the sulphide of iron, whilst the sulphide of cobalt and the sulphide of nickel remain undissolved, though the latter less completely. The sulphides of the metals are re-precipitated from the filtrate by the addition of ammonia and sulphide of ammonium, and the precipitate is treated once more with dilute hydrochloric acid. The results are nearly accurate. The cobalt and nickel can be determined by Liebig's method, as given above.

Nickel is separated from manganese and zinc by the annexed process of Ebelmen. Put the weighed mixture of the oxides in a small platinum vessel, insert this into a tube, heat the mixture to dull redness, conducting all the time sulphide of hydrogen gas over it. Let the sulphides formed cool in the gaseous stream, and then digest them for several hours with cold dilute hydrochloric acid, which dissolves only the sulphides of manganese and zinc. The sulphides of cobalt and nickel are left behind in a perfectly pure state, and may be separated, if desired, as above, by dissolving in aqua regia, *et cetera*. The reader will find much valuable information with respect to nickel under Cobalt, Vol. I., page 492.

Alloys of Nickel.—Faraday states that meteoric iron has been imitated by fusing iron with nickel. The alloy of ninety iron with ten nickel is of a whitish-yellow cast, and not so malleable as pure iron. The alloy with three per cent. of nickel is perfectly malleable and whiter than iron. These alloys are less disposed to rust than pure iron, but nickel alloyed with steel increases the tendency to rust.

Brande remarks that nothing is known of the alloys of nickel with *potassium, sodium, manganese, zinc*, or *tin*. With *copper* it forms a hard white alloy; the *white copper* of the Chinese, or *Pakfong*, consists, according to the analysis of Dr. Fyfe, of 40·4 parts of copper, 31·6 of nickel, 25·4 of zinc, and 2·6 of iron.

German Silver.—A similar alloy is often used as a substitute for silver, or for plated articles, under the name of *German silver*. It should consist of one part of nickel, one of zinc, and two of copper; or, when intended for rolling, of twenty-five parts of nickel, twenty of zinc, and sixty of copper; to which, if for *casting*, three of lead may be added. The following details respecting the alloys of nickel, are from a pamphlet on the subject by Messrs. TOPPING. The metals referred to should be as pure as possible. *Common German Silver.*—Copper 8, nickel 2, zinc 3·5. This is the commonest that can be made with any regard to the quality of the article produced, and may be used for ware for ordinary purposes. If the quantity of the nickel be reduced much below this, the alloy will be little better than pale brass, and tarnish rapidly. *Good German Silver.*—Copper 8 nickel 3, zinc 3·5. This is a very beautiful compound. It has the appearance of silver a little below standard; by some persons it is even preferred to the more expensive compounds. *Electrum.*—Copper 8, nickel, 4, zinc 3·5. This is the compound first introduced by Messrs. TOPPING, and they still prefer it to any of the others. It has a shade of blue like very highly-polished silver: it tarnishes less easily than silver.—Copper 8, nickel 6, zinc 3·5. This is the richest in nickel that can be made, without injuring the mechanical properties of the metal. It is a very beautiful compound, but requires a higher heat for fusion than the preceding, and will be found rather more difficult to work. *Tutenag.*—Copper 8, nickel 3, zinc 6·5. The proportions were originally obtained by analyzing a piece of Chinese tutenag of the best ordinary quality; but some rare specimens of Chinese tutenag, equal to electrum, have been seen. This alloy is very fusible, but very hard, and not easily rolled: it is best adapted for casting. A variety of articles are now plated with nickel by electrolytic precipitation from a solution of sulphate of nickel, the process being in all respects similar to that in which copper is used. SMEE recommends chloride of nickel as the solution, when electroplating with this metal, with a nickel positive pole and single battery: the nickel thus deposited, he says, is very brilliant, but rather brittle.

CHEMICAL COMBINATIONS. — Nickel forms two oxides: a protoxide, NiO—and a sesquioxide, Ni_2O_3.

Protoxide of Nickel may be procured in the anhydrous form by igniting the carbonate in a covered crucible, when it is left of an olive-green color. It may be precipitated from its salts by potassa, as a bulky light-green hydrate—NiO, HO—and may be obtained crystallized by boiling carbonate of nickel in ammonia. Oxide of nickel forms insoluble compounds with potassa or soda, which, however, may be decomposed with frequent affusions with boiling water. Baryta, strontia, and several other bases, also yield with it insoluble compounds; ammonia dissolves it, forming a deep-blue solution. When fused with borax, the oxide tinges the glass of a hyacinth yellow, which becomes less intense on cooling.

Sesquioxide—Ni_2O_3—is a black powder, which may be procured by treating the hydrated protoxide with a solution of chloroxide of sodium. It is singular that it does not combine with acids, but gives off a portion of its oxygen by ignition, or by heating with nitric or sulphuric acids, which form with it salts of the *protoxide*.

Sulphide of Nickel—NiS—occurs native in greyish or yellowish capillary crystals; it may be produced artificially by fusion, and can be obtained as a black hydrate, when a salt of nickel is precipitated by sulphide of ammonium.

Chloride of Nickel—$NiCl + 9HO$—is formed by dissolving the oxide in hydrochloric acid.

Sulphate of Nickel—$NiO, SO_3 + 6HO$—which results from the action of sulphuric acid on the metal, or its oxide, crystallizes in green rhombic prisms; these, when exposed to light, are converted, without loss of water, into small regular octohedra, aggregated together in the form of the original crystal, which becomes opaque.

CHARACTERS OF THE SALTS OF NICKEL.—The salts of this metal are of a delicate green hue, both when in the solid state and in solution. They have a sweetish astringent metollic taste.

Before the blowpipe, salts of nickel give, in the oxidating flame, with biborate of soda, a reddish-yellow glass, which becomes much paler as it cools. In the reducing flame, greyish particles of reduced nickel are disseminated through the bead.

In solution *sulphide of hydrogen* gives no precipitate, if the liquid be acidulated with sulphuric acid. *Sulphide of ammonium* gives a black sulphide. *Ammonia* gives a pale-green deposit, soluble in excess of ammonia, forming a bright blue solution. *Potassa* and *soda* throw down a pale-green bulky hydrated oxide of nickel. The *carbonates of the alkalies* give a pale apple-green precipitate of basic carbonate of nickel, which is readily soluble in carbonate of ammonia. *Ferrocyanide of potassium* affords a greenish white, and *ferridcyanide of potassium* a yellowish-green precipitate.

ANALYSIS.—Protoxide of nickel is always weighed as such. Mix the acid solution of the oxide in a beaker glass with pure potassa, or soda in excess, heat for some time to near boiling, filter, wash the precipitate thoroughly with hot water, dry, and ignite. The presence of ammoniacal salts, or of free ammonia, does not interfere with the precipitation. This method, if carefully executed, gives exceedingly accurate results, which the Editor has often confirmed.

USES.—The nickel obtained in this country, is chiefly employed for the manufacture of Argentane or German silver, which, as stated above, is an alloy of this metal with zinc and copper. Nickel likewise forms one of the constituents of the tutenag of China, and the *Pakfong* of the East Indies. Being exclusively used as an alloy, the nickel of commerce comes into the market in the form of finely-divided grains, or granulations, of the size of small beans. The best German silver consists of eight parts of copper, three of nickel, and three and a half parts of zinc; but an inferior and more common variety is sometimes manufactured from eight parts of copper, two of nickel, and four of zinc. From its magnetic property, a patent has been taken to substitute nickel for the magnetised steel needles employed in COOKE and WHEATSTONE's Electric Telegraph; but it has not been practically applied to this purpose.

NITRIC ACID.—*Acide nitrique*, French; *Salpetersäure*, German; *Acidum nitricum*, Latin.—An interesting paper appeared some time ago, by Mr. THORNTON J. HERAPATH, intended to show that this acid was known to the ancient Egyptians. In his *brochure* Mr. HERAPATH gave a short account of some experiments he had made on certain hieroglyphical marks or letters that had been discovered on the wrappers of a mummy which was unrolled by Mr. NASH at the Bristol Microscopical Society, and, as the result of these, he stated his belief that the ancient Egyptians were acquainted with a marking fluid containing nitrate of silver for its basis, and were also familiar with the use of nitric acid. A short time afterwards, Mr. DENHAM SMITH, in replying to this paper, took exception to these views; and whilst admitting the interesting nature of the discovery that had been made of an argentine solution having been employed some three thousand years ago, as *marking ink*, totally dissented from the conclusions that had been founded on it, inasmuch, he said, as there was no evidence to prove that the Egyptians were even versed in the art of distillation. He also hazarded the opinion, unsupported, however, by direct evidence, that the marking fluid in question was prepared by dissolving either the chloride or oxide of silver in an ammoniacal solution, and, consequently, without the intervention of any acid whatever. As the question in dispute is one of great interest, in a scientific point of view, Mr. HERAPATH pursued the subject, and submitted the marks to a fresh examination. After making several preliminary experiments, he found that no results of any value could be obtained by the ordinary modes of analysis, and was therefore compelled, as a last resource, to call in the aid of the microscope.

On examining with this instrument some of the fibres of the bandages that were stained by the argentine ink, he found them to present a very singular appearance. The ends near the corroded parts of the fabric, were stained of a deep brown or black; but for some little distance beyond the blackened portion, the fabric had a pale yellow hue, as if, during the decomposition of the silver salt that had been employed as *marking ink*, the nitrogenous constituents of the tissue had been partially acted upon, and converted into xanthoproteic acid.

Between several of the fibres, and, in many places, adhering to their external surfaces, were found small particles of some organic tissue, which were tinged of a still deeper yellow than the fibres themselves. On subjecting some of the latter to the action of strong liquor ammonia, the yellow portions, particularly the altered intercellular substance, acquired a still darker hue, whilst those, on the contrary, which were stained by the reduced silver, became slightly paler, as if a part of the argentine film was soluble in that menstruum; though it should be observed that no further effect was produced on the stain, even by a lengthened digestion in ammonia. Now, upon making comparative experiments with a piece of the linen wrapper that had been previously marked in the ordinary manner with solution of nitrate of silver, the fibres were found to present an appearance very similar to that above described; the only difference being that the yellow coloration was not quite so palpable, and more of the silver stain was eradicated by the solution of ammonia; whereas, on the other hand, fibres that had been stained by solutions of chloride and oxide of silver in ammonia, were uniformly colored of a dark-brown or black, and exhibited no remnant of the yellow coloration.

On the whole, the results of Mr. HERAPATH's microscopic examination appear to justify the conclusion that the ancient Egyptians were really familiar with nitric acid and its uses; and actually employed the nitrate of silver as a marking fluid. In what way, however, they prepared the acid, whether by distillation of the nitrate of soda or of nitrate of potassa with sulphuric acid, may for ever remain a mystery.

Liquid or hydrated nitric acid was known in the seventh century to GEBER, who termed it *solutive water*. It is sometimes called *azotic acid*, and in the time of the alchemists, it was known as *aquafortis*—a name still retained. The nature of its constituents was shown by CAVENDISH in 1785, and their proportions were subsequently determined by DAVY, GAY-LUSSAC, and THOMSON. When nitrogen is mixed with twelve or fourteen times its bulk of hydrogen, and a jet of the gas is allowed to burn in air or in oxygen, water is formed, which has a sour taste and an acid reaction, from the simultaneous formation of a small quantity of nitric acid. In this case, the nitrogen burns by the aid of the heat developed during the combustion of the hydrogen, and the nitric acid combines at once with the water formed, which much increases its chemical stability. It was, indeed, owing to the accidental production of nitric acid in the course of his experiments on the formation of water by the combustion of hydrogen, that CAVENDISH was induced to institute the train of research which resulted in his important discovery.

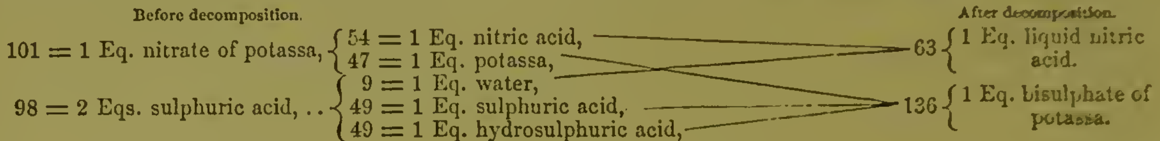
If two volumes of nitrogen be mixed with five volumes of oxygen in an inverted siphon containing a few drops of an infusion of litmus, each limb plunging into a separate glass of mercury, and a series of electric sparks be passed through the mixture, the two gases will slowly combine, and the litmus will be reddened. The heat of the spark determines combination of the gases just at the spot through which it passes, but the action does not extend further. In like manner, if a number of sparks be passed from the electrical machine, between two metallic points, over moistened litmus paper in air, a red spot will be produced upon the paper, owing to the formation of nitric acid in minute quantity by the combination of oxygen with nitrogen. During stormy weather, and, indeed, whenever a flash of lightning passes through a humid atmosphere, the same compound results in appreciable quantity. Indeed, rain water always contains traces of nitrate of ammonia, which may be detected, if the experiment is made with sufficient attention to accuracy.

Nitric acid also occurs in combination with potassa or soda, in the form of an efflorescence in the soil, especially in tropical climates, as in some parts of India and Peru. The compound formed with soda constitutes the *nitre*, and with potassa, the *saltpetre* of commerce.

Preparation.—It is either from nitrate of potassa or nitrate of soda that this acid is always obtained for chemical purposes. When saltpetre is heated with sulphuric acid, it is decomposed; an alkaline sulphate remains in the retort, whilst the more volatile nitric acid distils over, and may be condensed in the usual manner. In preparing nitric acid on the small scale, equal weights of nitre and concentrated sulphuric acid are placed in a glass retort, and carefully distilled. The result of the reaction may be traced as follows:—

$$\underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} + \underbrace{2\,(HO, SO_3)}_{\text{Sulphuric acid.}} = \underbrace{HO, NO_5}_{\text{Nitric acid.}} + \underbrace{(KO\ SO_3, HO\ SO_3)}_{\text{Bisulphate of potassa.}}$$

or, as it may be illustrated more in detail:—



Before decomposition.

101 = 1 Eq. nitrate of potassa, { 54 = 1 Eq. nitric acid, / 47 = 1 Eq. potassa,

98 = 2 Eqs. sulphuric acid, .. { 9 = 1 Eq. water, / 49 = 1 Eq. sulphuric acid, / 49 = 1 Eq. hydrosulphuric acid,

After decomposition.

63 { 1 Eq. liquid nitric acid.

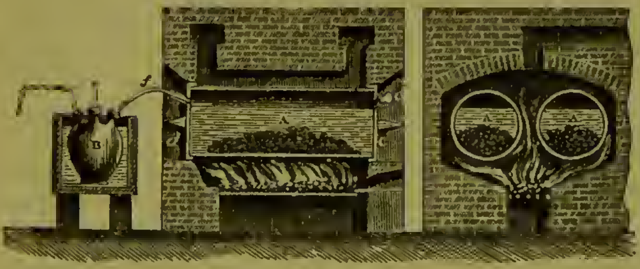
136 { 1 Eq. bisulphate of potassa.

Red vapors appear in the retort during the distillation, arising from partial decomposition of the acid, and a formation of some of the lower oxides of nitrogen. A yellowish corrosive liquid condenses in the receiver, fuming strongly on exposure to the air, and emitting a powerful, irritating odor.

On the large scale, iron retorts, Fig. 370, coated with fire-clay on the inside of the upper part, where they are exposed to the acid vapors, are employed for the distillation, and nitrate of soda is substituted for the potassa salt, being cheaper, and likewise containing considerably more nitric acid.

The cylinders or retorts are arranged in pairs in a furnace, so that each fire heats two cylinders, as shown in the transverse section. They are furnished with a movable lid, *c*, *d*, at each end. The nitrate is introduced into the retort, A, through the aperture at *c*, which is closed during the distillation, by a stone lid that fits accurately; the sulphuric acid being introduced by a funnel at *e*, after the retort is closed. As soon as the acid is added, the funnel is withdrawn, and the opening closed with a plug. The acid, as it distils over, passes through the pipe, *f*, and is condensed in a series of stoneware bottles, the first of which is seen at B. The acid which condenses in the first receiver, is always contaminated with sulphuric acid, and that in the last is rather dilute, as water is placed in it to condense the nitrous fumes.

Fig 370.



It is usual upon the large scale to employ a smaller proportion of sulphuric acid than when the distillation is performed in glass vessels, as it is quite possible to effect a complete decomposition of the nitrate by heating it with one-half its weight of sulphuric acid. Under these circumstances, however, a higher temperature is needed to expel the last portions of acid, and a considerable quantity of the nitric acid is thereby decomposed and wasted. The residue in the retort, when the smaller quantity of sulphuric acid is used, is much less soluble in water, and consequently is much more difficult of removal; in the iron cylinder of the manufacturer, this is of no moment, as the saline mass can easily be detached by the use of iron tools, when the distillation is at an end. The cause of these differences lies in the fact that sulphuric acid forms with potassa two different compounds, one of which contains twice as much acid as the other. When saltpetre and sulphuric acid are mixed in the proportion of two equivalents of each, half the salt only is decomposed, so long as a gentle heat is employed, and the acid sulphate of potassa is formed. The nitric acid, thus liberated, distils over readily. Annexed is represented the form of this reaction:—

$$\underbrace{2\,(KO, NO_5)}_{\text{Nitrate of potassa.}} + \underbrace{2\,(HO, SO_3)}_{\text{Sulphuric acid.}}$$

yielding

$$\underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} + \underbrace{HO, NO_5}_{\text{Nitric acid.}} + \underbrace{(HO\ SO_3, KO\ SO_3)}_{\text{Bisulphate of potassa.}}$$

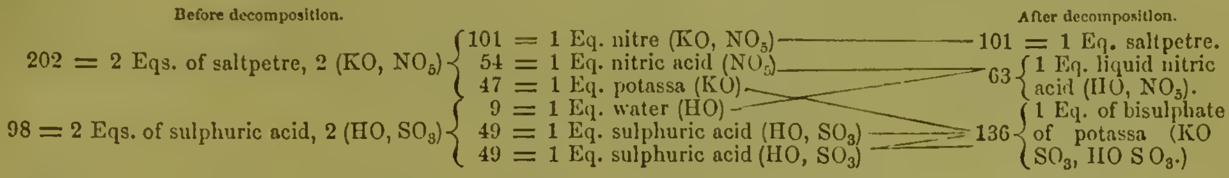
As soon as the first half of the nitric acid has passed over, the temperature begins to rise, and the bisulphate of potassa then reacts on the undecomposed saltpetre; the second half of the nitric acid is liberated, but at the same time is partially decomposed towards the end of the operation, and the whole of the potassa remains in combination with sulphuric acid in the form of the sparingly soluble neutral sulphate. This second stage of the decomposition is exhibited in the subjoined equation, which will be easily understood from the foregoing:—

$$\underbrace{(KO, NO_5)}_{\text{Nitrate of potassa.}} + \underbrace{(HO, SO_3, KOSO_3)}_{\text{Bisulphate of potassa}} = \underbrace{HO, NO_5}_{\text{Nitric acid.}} + \underbrace{2\,(KO, SO_3)}_{\text{Sulphate of potassa.}}$$

When, on the other hand, two equivalents of sulphuric acid are used to one of nitrate of potassa, the whole of the potassa is at once converted into the acid sulphate, so that the total quantity of the nitric acid is liberated immediately, and distils readily:—

$$\underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} + \underbrace{2\,(HO, SO_3)}_{\text{Sulphuric acid.}} = \underbrace{(HO, NO_5)}_{\text{Nitric acid.}} + \underbrace{HO\ SO_3\ KO, SO_3}_{\text{Bisulphate of potassa.}}$$

The result is, therefore, one equivalent of the bisulphate of potassa, and one of nitric acid. These changes will perhaps be better understood by the following tabulation :—


Before decomposition.
202 = 2 Eqs. of saltpetre, 2 (KO, NO₅)
98 = 2 Eqs. of sulphuric acid, 2 (HO, SO₃)
101 = 1 Eq. nitre (KO, NO₅)
54 = 1 Eq. nitric acid (NO₅)
47 = 1 Eq. potassa (KO)
9 = 1 Eq. water (HO)
49 = 1 Eq. sulphuric acid (HO, SO₃)
49 = 1 Eq. sulphuric acid (HO, SO₃)
After decomposition.
101 = 1 Eq. saltpetre.
63 1 Eq. liquid nitric acid (HO, NO₅).
136 1 Eq. of bisulphate of potassa (KO SO₃, HO S O₃.)

PROPERTIES.—In the most concentrated state in which it can be obtained by the preceding process, nitric acid is, when pure, a colorless, limpid, fuming, powerfully-corrosive liquid, having a specific gravity of 1·520. It is the highest oxide of nitrogen known to exist, and contains one equivalent of nitrogen with five of oxygen, associated with one equivalent of water—HO, NO_5. One hundred parts contain 85·71 of the anhydrous nitric acid. Exposure to the light of the sun produces its partial decomposition; mere distillation, in fact, has invariably the same effect. At 184° it begins to boil, and congelation occurs about 40° below zero. It very readily parts with a portion of its oxygen to the metals, and to combustible bodies. If it be dropped into hot, finely-powdered charcoal, the charcoal burns vividly; if mixed with a little sulphuric acid and poured into oil of turpentine, the mixture bursts into flame. Nitric acid has a pungent, rather disagreeable smell, is very acid and corrosive, and stains the skin, and organic matter in general, yellow.

It has a strong attraction for water, and becomes hot when mixed with it. Acid of medium strength, mixed with snow, causes it to liquefy instantly, producing intense cold. Nitric acid acts violently upon tin or iron filings, especially if they be previously moistened with a few drops of water: this acid is, indeed, constantly employed by the chemist as an oxidising agent. In order to produce a rapid oxidation of the metals, it is best to dilute the acid until it has a specific gravity between 1·25 and 1·35.

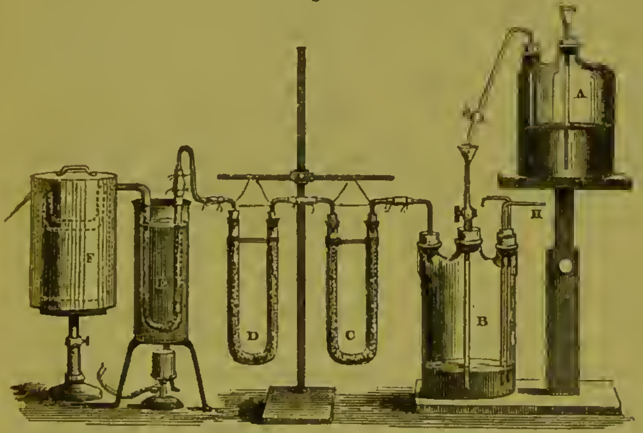
The action of nitric acid upon the metals is instructive, and it is well remarked by MILLER, from whose excellent work the Editor has largely drawn in the present article, that this action may serve to illustrate the manner in which metallic bodies combine with the acids generally. The metals, he observes, will enter into direct combination with many of the simple non-metallic bodies: thus, antimony will unite directly with chlorine, and will even take fire if allowed to fall in fine powder into the gas. Iron will burn in oxygen; and copper turnings, if mixed with powdered sulphur, will combine with the sulphur on the application of heat, emitting a vivid flash of light. But no metal will unite directly with an acid; in order that the combination between them should occur, it is necessary that the metal should be in the form of oxide. This oxidation, may, however, be effected at the same time that the acid is presented to the metal, and the formation of the oxide and its solution may appear to occur simultaneously. Zinc, for example, does not unite as zinc with sulphuric acid: when this metal is placed in dilute sulphuric acid, the oxygen is supplied from the water which is decomposed, oxide of zinc is produced, and is immediately dissolved by the acid, whilst the hydrogen escapes in the gaseous form. When a metal, such as copper or silver, is dissolved by nitric acid, a preliminary oxidation is equally necessary; but owing to the facility with which nitric acid is deprived of a part of its oxygen, this oxidation is usually effected at the expense of the nitric acid, which is more readily decomposed than water; some of the lower oxides of nitrogen are liberated in the form of ruddy fumes, whilst the compound of the metal with oxygen dissolves in another portion of the acid which has remained intact. The exact nature of the decomposition which the nitric acid experiences varies in different cases. Silver, when allowed to dissolve slowly in the cold in dilute nitric acid, produces nitrous acid—NO_3—which remains in solution: thus, $2\ Ag + 3\ NO_5$ becomes $2\ (AgO, NO_5) + NO_3$, and the metal dissolves without evolution of gas; and a similar effect is produced by palladium. With metals which, like copper and mercury, have a somewhat stronger affinity for oxygen, binoxide of nitrogen—NO_2—is disengaged in large quantity; for example, $3\ Cu + 4\ NO_5 = No_2 + 3\ (CuN, NO_5)$; and if the metal have a still more powerful tendency to combine with oxygen, as is the case with zinc, the protoxide of nitrogen—NO—is, if the acid be dilute, amongst the vapors disengaged: $4\ Zn + 5\ NO_5$ would produce $NO + 4\ (Zn\ O, NO_5)$. Zinc and tin also decompose water as well as nitric acid when dissolved in the acid, eliminating hydrogen, which, as soon as it is evolved, completely deprives a portion of nitric acid of its oxygen, and forms *ammonia* by entering into combination with the liberated nitrogen; for instance, $8\ Zn + 8\ HO + 8\ NO_5 = 8\ (ZnO, NO_5) + 8\ H$, and $NO_5 + 8\ H$ yield $5\ HO + NH_3$.

When the concentrated acid is exposed to the air it imbibes moisture; and if mixed with water it absorbs a sensible amount of heat, owing to the formation of another hydrate of much greater persistency. This stable hydrate contains four equivalents of water, and one of nitric acid ($HO, NO_5 + 3$ Aq.); it has a specific gravity of 1·424, and is composed of sixty per cent. of anhydrous acid, and forty of water. This hydrate has a higher boiling point than the protohydrate, and distils at 250° unaltered.

Anhydrous Nitric Acid.—Nitric acid, says MILLER, may be obtained anhydrous by DEVILLE's method, in which state it forms perfectly transparent, brilliant, colorless crystals, derived from the right rhombic prism; they melt at 85°, and boil at 113°; at about this temperature the compound begins to be metamorphosed. Sometimes the crystals, even if kept in sealed tubes, undergo decomposition at the ordinary atmospheric temperature, and the tube bursts with a dangerous explosion from the pressure exerted by the liberated gases. The crystals dissolve rapidly in water, emitting much heat, and producing ordinary nitric acid.

The process consists in passing a uniform current of perfectly exsiccated chlorine gas very slowly over crystals of well-dried nitrate of silver; the salt is heated to about 200° at first, till the decomposition has commenced, and the temperature is then lowered to about 150°. The operation is one of considerable delicacy, and requires attention to a number of minute precautions, for the details of which the reader is referred to M. DEVILLE's paper. The apparatus required is shown in Fig. 371. A is a vessel of concentrated sulphuric acid; the acid is drawn off from it by the siphon, and allowed to flow into the vessel B, in a very slender stream, which can be regulated by the glass stopcock; B has also been filled with sulphuric acid, and subsequently charged with pure dry chlorine, by means of the bent tube, H. C is a tube filled with dry chloride of calcium; D a tube filled with pumice moistened with sulphuric acid; E a tube filled with nitrate of silver in crystals, immersed in a bath of oil; F the receiver for the anhydrous nitric acid, which is kept cool by a mixture of ice and salt. The tubes E and F are made of one continuous piece of glass, as the acid immediately attacks and destroys cork or caoutchouc joints; a portion of one of the lower oxides of nitrogen is liquefied and collected in the tube in F, and is then separated. The chlorine displaces the nitric acid and oxygen from the nitrate of silver; chloride of silver is formed, and the nitric acid and oxygen escape. By surrounding the receiver, F, with a freezing mixture, the nitric acid is condensed in crystals. The decomposition is of the following simple character:—

Fig. 371.



$$\underbrace{Ag\,O,\,NO_5}_{\text{Nitrate of silver.}} + \underbrace{Cl}_{\text{Chlorine.}} \text{ give } \underbrace{Ag\,Cl}_{\text{Chloride of silver.}} + \underbrace{O}_{\text{Oxygen.}} + \underbrace{NO_5}_{\text{Nitric acid.}}$$

The composition of anhydrous nitric acid was determined by DEVILLE, by estimating the quantity of nitrogen which a given weight of the acid furnished after the oxygen had been removed from it by heating it in contact with copper, which rapidly combines with oxygen at a higher temperature. M. DEVILLE found in one of his experiments, that five hundred and forty-seven milligrammes of acid, gave one hundred and sixteen cubic centimetres of nitrogen, at a temperature of 41°, whilst moist, and under a barometric pressure of seven hundred and fifty-seven millimetres. This, when corrected, gives in one hundred parts of the acid by weight, 25·9 of nitrogen; the deficiency, 74·1, is oxygen; or fourteen parts of nitrogen are united with forty of oxygen.—*Miller.*

The subjoined is an abridgment of a table, giving the per-centage of anhydrous nitric acid contained in aqueous solutions of various specific gravities, as determined by Dr. URE:—

Specific gravity.	NO_5 in one hundred parts by weight.	Specific gravity.	NO_5 in one hundred parts by weight.
1·5000	79·700	1·2887	39·053
1·4940	77·303	1·2705	36·662
1·4850	74·918	1·2523	34·271
1·4760	72·527	1·2341	31·880
1·4670	70·136	1·2148	29·489
1·4570	67·745	1·1958	27·098
1·4460	65·354	1·1770	24·707
1·4346	62·963	1·1587	22·316
1·4228	60·572	1·1403	19·925
1·4107	58·181	1·1227	17·534
1·3978	55·790	1·1051	15·143
1·3833	53·399	1·0878	12·752
1·3681	51·068	1·0708	10·361
1·3529	48·617	1·0540	7·970
1·3376	46·226	1·0375	5·579
1·3216	43·835	1·0212	3·188
1·3056	41·444	1·0053	0·797

Tests for Nitric Acid.—No ready method is known of precipitating nitric acid from its solutions, since all its compounds dissolve more or less freely in water. Various indirect methods have been recommended for discovering its presence. One of the best consists in neutralizing the solution, if acid, with potassa, and evaporating nearly to dryness; then adding a few copper filings, and heating the mixture with a little sulphuric acid. The copper combines with a portion of the oxygen of the nitric acid, and decomposes it, while characteristic red fumes of binoxide of nitrogen show themselves, if nitric acid be present. A still smaller quantity of the acid may be detected by substituting a crystal of protosulphate of iron for the copper, before adding the sulphuric acid; on the application of a gentle heat in this case, the characteristic action consists in the formation of an olive-green solution, the color of which disappears on boiling. The nitrous acid gas, formed by the deoxidising action of one portion of the ferruginous salt, dissolves, with the distinctive green color, in the solution of the unoxidised part of the salt. If a few drops of hydrochloric acid be added to a solution which contains free nitric acid, or a nitrate dissolved, the liquid acquires the power of dissolving gold leaf. This effect, however, is produced by hydrochloric acid in solutions of the iodates, chlorates, and bromates, but the presence of these salts may be detected by other characters. PRICE's test for the detection of iodine, and which is described at page 403, is equally applicable for the detection of nitric acid.

QUANTITATIVE ESTIMATION.—MARTIN separates the ammonia present in the substance to be examined from the nitric acid, by boiling it with potassa. He then introduces the resulting solution into a vessel, with metallic zinc, and a sufficient quantity of water, and adds by degrees hydrochloric or sulphuric acid. By these means the nitric acid is completely converted into ammonia, and its amount may now be arrived at by the usual methods for estimating that alkali, Vol. I., page 198. Seventeen of ammonia, NH_3, represent fifty-four of nitric acid, NO_5.

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